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PRODUCTION RELATIONSHIPS IN THE ATLANTIC GROUNDFISH INDUSTRY: AN ECONOMIC ANALYSIS

BY

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With love

to

Mom and Dad Cro

and

Button

Abstract

In 1977, the Canadian Government assumed control of the total allowable catch of sea fish of both Canadian and foreign fleets within 200 nautical miles off Canada's east coast, in order to build up badly depleted stocks of commercially important species and reduce the economic instability which has plagued the Atlantic sea fish system. The annual total allowable catch of groundfish within this newly acquired area has been established and projected into the mid-1980's. Government projections indicate that, although stocks are being allowed to build, the total allowable catch of groundfish will also build from 680,000 metric tons in 1978 to approximately 970,000 metric tons in 1985.

This thesis presents an empirical investigation which attempts to quantify the factors that determine the demand for labour in the Atlantic groundfish industry, in order to ascertain (a) what the impact of increased output on employment might be, (b) what the likely effect of alternative allocations of a fixed amount of output on employment might be, (c) what the likely effects of alternative forms of subsidization on employment might be and (d) what the effects of technological change in the fisheries might be on employment.

The constant elasticity of substitution (C.E.S.) production function was used to characterize the physical-technical aspects of production. This production function was incorporated into an economic model of the Atlantic groundfish industry and single equation econometric techniques were used to test the model. Two equations were fitted, the factor proportions equation and the demand for labour

equation. Although representative data was a limiting factor, some evidence was provided against the "Cobb Douglas" hypothesis, that the elasticity of substitution between capital and labour (σ) = 1 and the "Leontieff" hypothesis, that (σ) = 0. The study did indicate that the elasticity of substitution between capital and labour in production is somewhat less than unity. Disembodied technical change, which was capital using, was found to be occurring at the rate of approximately 1.8% for each new vintage. Although it was not possible to secure any precise estimate of technical efficiency, the study did indicate differences in returns to scale on the basis of the scale of operation and for each scale returns were increasing.

It is apparent that there are many different vintages of capital employed in production in the Atlantic groundfish industry in any one season. Furthermore, these vintages exhibit a different abstract technology, definable in terms of the concept of the production function.

Although the results are highly conditional due to severe data limitations, certain policy implications are brought to light concerning the impact of expanded output, the likely effect of alternative quota allocation programs and various subsidization programs on the industry demand for labour.

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I should like to take this opportunity to sincerely thank a number of persons who took the time and effort (and occasionally trouble) to help in my personal development in life.

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CHAPTER I

INTRODUCTION

Early in 1977, the Canadian government extended its international boundaries in the ocean from 12 to 200 nautical miles and, in so doing, assumed control of Canadian and foreign catches of sea fish within the newly specified boundaries.

Canada's sea fish system is quite important to the provincial economies on Canada's Atlantic coast in terms of employment, wages and salaries, output and international commodity trade. This importance is underlined by the fact that economic conditions in the Atlantic provinces have been depressed relative to the rest of Canada for the last few decades. Furthermore, there has been much speculation by bodies with vested interest as to what the 200 mile limit can mean for the Atlantic provinces. Nova Scotia's Fisheries Minister, Daniel Reed, stated:

> ...fishing could well become the number one industry in the province with a projected value of $800 million annually; it ranks fourth now. It could account for 25% of Nova Scotia's exports by 1985 and provide 3 times the 11,000 jobs it does today.[1]

Newfoundland's Premier, Frank Moore, stated:

> If we handle it (management of the fisheries resource) properly, the number of jobs related to the fishing industry should double in 5 years and number 25,000. If we catch 50% of the fish instead of just 25% and land it in our province, it will mean 2,500 jobs in trawlers, 600 in the service industry and 8,000 for the processing plants.[2]

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[1] J.M. Fox, "Cashing in on the 200 Mile Catch," Financial Post (June 9, 1977).

[2] Ibid.

It is apparent that there are high hopes that government regulation of the sea fish catch within the 200 mile limit can revitalize the sea fish system and generate a substantial increase in employment in the Atlantic provinces.

Purpose

The purpose of this thesis is to quantify the factors affecting employment in the Atlantic groundfish industry. Although groundfish represent only a few of the total number of species with commercial value caught on the Atlantic coast, they nevertheless account for a large component of the value of sea fish caught in that area.

Neoclassical economic theory postulates that, in a competitive industry, the demand for labour is a function of the wage rate, the interest rate, the level of output, and the abstract technology embedded in the production process in that industry. Currently, little is known of the technical-economic relationships which affect the demand for labour in the Atlantic groundfish industry. Economic theory indicates the relevant variables to be included in the demand function and even what sign should be attached to the explanatory variables. However, here the usefulness of economic theory fades as it provides us with qualitative estimates. In order to obtain a better assessment of the potential impact that government policy might generate on employment in the Atlantic groundfish industry, there is a need to obtain quantitative estimates of the relevant parameters.

Objectives

The primary objectives of this thesis are:

1) To estimate the abstract technology embedded in the process of extracting groundfish from the ocean in the Atlantic groundfish industry;

2) To obtain an idea of how the abstract technology underlying the extraction process has changed over time and, consequently, how the demand for labour in the Atlantic groundfish industry has been affected;

3) To estimate the employment-output relationship in the Atlantic groundfish industry; and

4) To indicate how the information obtained above can be utilized to guide economic policy in the Atlantic groundfish industry.

Empirical Setting—Methodology

The physical setting which is used for empirical investigation in this study may be seen in Figure 1. It encompasses that area of ocean on the Atlantic coast which is bounded on the offshore side by the 200 mile limit. Although the 200 mile limit did not come into effect until 1977, over 95% of the Canadian catch has traditionally been caught in this area.[3]

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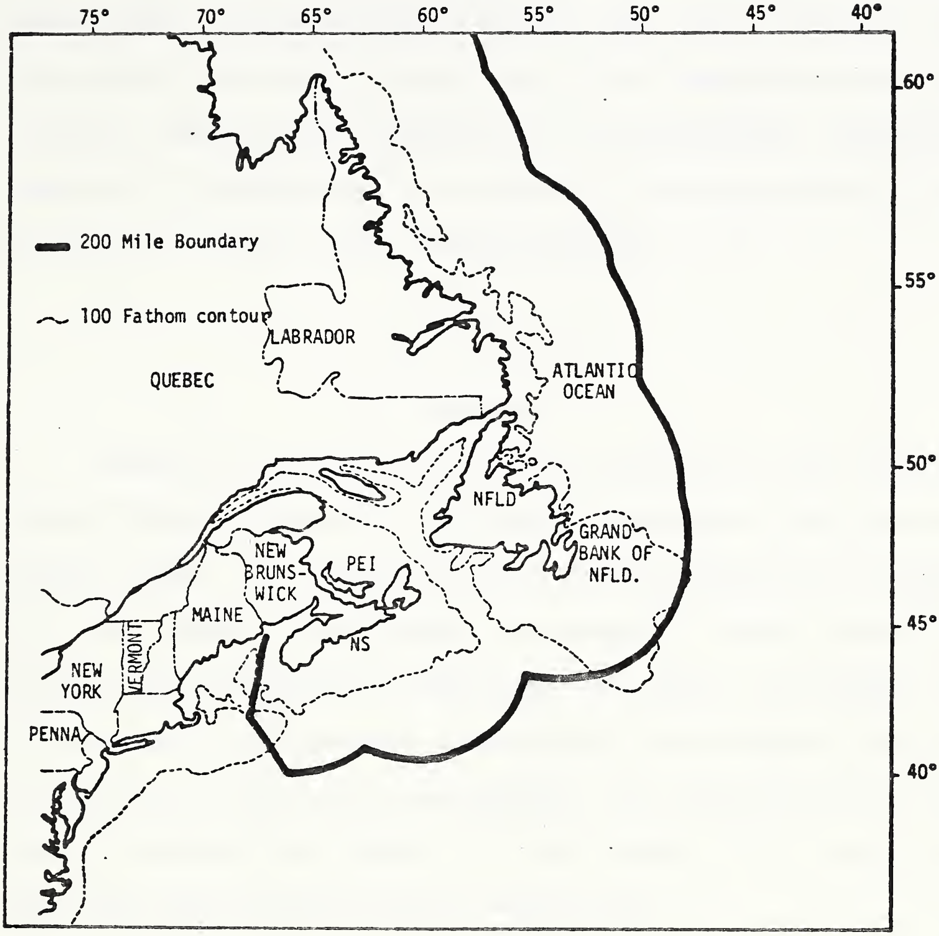
[3] This observation was derived from a comparison of the Canadian catch of groundfish inside the 200 mile limit and the Canadian catch of groundfish in the much larger International Commission area. It is assumed that the entire Canadian catch of groundfish is obtained within the International Commission area.

FIGURE I

Limit of Canadian Fishing Jurisdiction:
"The 200 Mile Limit"



Source: Fisheries and Marine Service, Department of Fisheries and the Environment.

An econometric model is built which employs cross sectional observations of representative vessels over time. Initially all observations are viewed as being part of one homogeneous production function, however the possibility of heterogeneous production functions is investigated. The econometric techniques used to test the model are based on single equation methods.

Procedure

Chapter II provides a descriptive analysis of the sea fish system in Canada, indicating the economic importance of the system in certain regions. The relevant economic theory is presented in Chapter III. This chapter also includes an econometric model proposed to estimate the determinants of the demand for labour. In Chapter IV, estimates of the relationships postulated in the econometric model are provided, as are the tests of hypothesis. The appropriateness of the model is discussed in Chapter V in the context of its explanatory power, data limitations and policy implications.

CHAPTER II

THE COMMERCIAL SEA FISH SYSTEM IN THE CANADIAN ECONOMY

Introduction

Canada's commercial sea fish system as defined in this study consists of three sectors: the primary sector, the processing sector and the retail sector. Each sector may be broken down into a number of industries. The primary sector, for example, includes those industries involved in extracting sea fish from the ocean. The processing sector consists of those industries involved in transforming sea fish from natural to marketable form. The retail sector includes those industries involved in selling fish to the consumer. This study isolates on a particular industry in the primary sector.

According to Webster's dictionary, an industry consists of:

> ...a group of productive or profit making enterprises, or organizations which have similar technological structures of production and that produce technically substitutable goods, services or sources of income.[4]

Apparently, then, the division of a sector into various industries is rather subjective, depending upon how "similar" the technological structures of production are and how "technically substitutable" the goods being produced are. For purposes of this thesis, however, the primary sector is viewed as consisting of a number of industries—the groundfish industry, the lobster industry, the scallop industry, and so on. Although the groundfish industry covers a

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[4] Webster's Third New International Dictionary.

number of species of sea fish, they are caught with a "similar technological structure of production" and are, to an extent, technically substitutable goods. On the other hand, lobsters and scallops can be individually separated from other industries in the primary sector because the productive techniques employed to catch them are highly specialized. Hereafter the Atlantic groundfish industry refers to firms (or that part of vertically integrated firms) engaged in extracting groundfish from the Atlantic Ocean.

Economic Importance[5]

Output

In 1975, the primary and processing sectors of the sea fish system in Canada generated $455,554,000 in terms of value added or .3% of Gross National Product (Table I). It is apparent that the contribution of this part of the sea fish system to G.N.P. is slowly dropping (from .4% of G.N.P. in 1961 to .3% of G.N.P. in 1975) as seen in Table I.

However, a different picture unfolds if Canada is divided into the following regions: Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Central Canada[6] and British Columbia. Although British Columbia generated more value added in the primary and processing sectors (combined) than any other region during the years 1961, 1966, 1971 and 1975, it has consistently

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[5] Unfortunately, in discussing output, employment and wages, the latest data available in the processing industry were for 1975. In order to retain consistency, employment and wages and salaries were measured over the same period in the primary and processing sectors.

[6] Central Canada consists of Ontario, Manitoba, Saskatchewan and Alberta

TABLE I

The Value Added in the Primary and Processing Sea Fish Industries in Canada, by Region:
For the Periods 1961, 1966, 1971 and 1975

(In Current $000's and as a % of Gross Domestic Product)

Value Added in the Primary and Processing Sea Fish Industries	Newfoundland		P.E.I.		Nova Scotia		New Brunswick		Quebec		Central Canada		British Columbia		Canada	
	$000's	%	$000's	%	$000's	%	$000's	%	$000's	%	$000's	%	$000's	%	$000's	%
							1961									
Primary 1/	14,717	2.9	4,173	3.7	27,152	2.5	7,594	.9	4,187	.	---	.	38,778	1.0	96,601	.2
Processing 2/	8,420	1.7	750	.7	15,139	1.4	6,189	.8	2,100	.	---	.	28,336	.7	60,934	.2
Total	23,137	4.6	4,923	4.3	42,291	4.0	13,783	1.7	6,287	.1	---	.	67,114	1.6	157,535	.4
Gross Domestic Product 3/	505,900		114,000		1,066,200		800,000		10,576,100		23,034,300		4,068,600		40,165,000	
							1966									
Primary	25,886	3.2	5,998	3.6	46,738	3.1	11,005	.9	6,681	.	---	.	60,659	.9	156,967	.3
Processing	18,001	2.2	1,363	.8	27,700	1.8	9,680	.8	4,343	.	---	.	32,534	.5	93,621	.1
Total	43,887	5.5	7,371	4.4	74,438	5.0	20,684	1.7	11,024	.1	---	.	93,193	1.4	250,588	.4
Gross Domestic Product	800,700		165,500		1,502,000		1,185,700		16,325,600		36,177,300		6,549,300		62,706,100	
							1971									
Primary	35,808	2.8	9,426	3.7	57,660	2.4	15,959	.9	10,296	.	---	.	58,588	.6	187,737	.2
Processing	35,637	2.8	5,736	2.2	29,668	1.3	14,685	.8	10,744	.	---	.	38,938	.4	135,408	.1
Total	71,445	5.6	15,162	5.9	87,328	3.7	30,644	1.7	21,040	.1	---	.	97,526	.9	323,145	.3
Gross Domestic Product	1,271,300		257,200		2,357,600		1,775,500		23,796,300		55,129,800		10,482,800		95,070,500	
							1975									
Primary	44,005	2.1	10,806	2.4	90,419	2.2	24,930	.8	14,449	.	---	.	79,681	.4	264,290	.2
Processing	36,330	1.7	4,314	1.0	52,497	1.3	22,207	.7	13,359	.	---	.	64,557	.3	193,264	.1
Total	80,335	3.8	15,120	3.4	142,916	3.5	47,137	1.5	27,808	.1	---	.	144,238	.7	457,554	.3
Gross Domestic Product	2,096,700		447,400		4,037,600		3,224,200		39,850,400		99,046,000		19,414,600		168,116,900	

Note: --- Less than $1,000.
. Less than .1%.

Source: 1/ "Value of Fish Landed", Statistics Canada Fisheries Statistics #24-201-24-212.
2/ "Value Added in Manufacturing", Statistics Canada Manufacturing Industries of Canada: National and Provincial Areas #31-203.
3/ "Provincial Gross Domestic Product at Market Prices" was obtained from Statistics Canada "Provincial Economic Accounts #13-213.

ranked behind each of the Atlantic provinces in terms of the relative contribution to Gross Provincial Product (Table I). Amongst the Atlantic provinces, the primary and processing sectors of the sea fish system in Newfoundland provide the greatest relative contribution to G.P.P. They comprised 4.6% of Newfoundland's G.P.P. in 1961 and climbed to 5.6% in 1971 before decreasing to 3.8% in 1975 (Table I). In terms of the absolute amount of value added in these two sectors in the Atlantic provinces, however, Newfoundland has traditionally ranked second to Nova Scotia, generating about two-thirds of Nova Scotia's value of output.

Apparently, the primary and processing sectors of Canada's sea fish system are insignificant in terms of their contribution to G.N.P. However, they are of some importance to certain regions, most noticeably, the Atlantic provinces.

Consumer Expenditure

It is difficult to measure the value added in the retail sector of the sea fish system as no specific information in this regard is published. However, one measure of the regional importance of the retail industry is available in the 1969 Food Expenditure Survey[7] which is summarized in Food Consumption Patterns in Canada.[8] According to this source, consumer expenditure on fish at home averaged just over seven dollars per capita in 1969, ranging from just nine dollars in the Atlantic

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[7] Statistics Canada, Family Food Expenditure in Canada (1969), Vol. I and II, pp. 61-531.

[8] Z.A. Hassan and W.F. Lu, Food Consumption Patterns in Canada (1974), Economics Branch, Agriculture Canada.

TABLE II

Consumer Expenditure on Fish at Home in Canada, by Region (1969)

Region	Per Capita Fish Expenditure	Population	Percentage of Total Population	Total Fish Expenditure	Percentage of Total Fish Expenditure
	$	'000	%	$'000	%
Atlantic Provinces	9.13	2,028	10	18,516	12
Quebec	5.67	5,985	28	33,935	23
Central Canada	7.36	10,881	52	80,125	54
British Columbia	8.19	2,060	10	16,871	11
Canada	7.19	20,954	100	149,447	100

Source: Food Consumption Patterns in Canada (1974), Economics Branch, Agriculture Canada.

provinces to about five and a half dollars in Quebec. Furthermore, taking into account the regional differences in population, it is estimated that approximately $150 million was spent on fish in Canada in 1969, of which 54% originated in Central Canada, 23% originated in Quebec, 12% originated in the Atlantic provinces and 11% originated in British Columbia (Table II).

It is apparent that consumer expenditure on sea fish (at home) is roughly directly proportional to the distribution of the populous in Canada and, as such, the retail sector in the sea fish system is more regionally dispersed than its primary and processing counterparts.

Employment

During 1961, the average number of persons employed in the primary and processing sectors of the commercial sea fish system in Canada was estimated at 47,000, .8% of national employment. By 1975, employment in the sea fish system had dropped to 46,000, .5% of national employment (Table III).

Using the same regions as previously defined, employment in the primary and processing sectors of the sea fish system has been absolutely and relatively more important in Newfoundland and Nova Scotia than in British Columbia, and relatively more important in Prince Edward Island and New Brunswick than in British Columbia (Table III). Within the Atlantic provinces, the absolute number of persons employed in the primary and processing sectors of the sea fish system and the relative contribution of those persons to the provincial employment has been highest in Newfoundland. However,

TABLE III

Employment in Canada's Primary and Processing Sea Fish Industries by Region:
For the Periods 1961, 1966, 1971 and 1975

(Average Number Employed per Year and as a % of Provincial Employment)

Primary and Processing Sea Fish Industries	Newfoundland Number	Newfoundland %	P.E.I. Number	P.E.I. %	Nova Scotia Number	Nova Scotia %	New Brunswick Number	New Brunswick %	Quebec Number	Quebec %	Central Canada Number	Central Canada %	British Columbia Number	British Columbia %	Canada Number	Canada %
1961																
Primary[1]	15,700	15.1	2,000	6.1	8,000	2.5	3,100	1.8	1,700	.1	---	.	3,400	.6	33,900	.5
Processing[2] 1)	2,715	2.6	355	1.1	3,505	1.5	2,202	1.3	966	.1	---	.	2,183	.4	11,926	.2
2)	281	.3	32	.1	455	.2	248	.1	83	.	---	.	622	.1	1,721	.
Total	18,696	18.0	2,387	7.2	11,960	5.2	5,550	3.3	2,749	.2	---	.	6,205	1.1	47,547	.8
Provincial Total[3]	104,000		33,000		229,000		169,000		1,703,000		3,457,000		551,000		6,246,000	
Unemployment Rate[3]	8.6		2.6		4.3		5.9		4.4		3.1		5.3		3.9	
1966																
Primary	16,600	13.5	1,600	4.6	8,600	3.6	2,700	1.5	2,100	.1	---	.	2,400	.4	34,000	.5
Processing 1)	4,008	3.2	430	1.2	4,614	1.9	2,326	1.3	1,173	.1	---	.	2,152	.3	14,703	.2
2)	446	.4	35	.1	586	.2	281	.2	77	.	---	.	1,238	.2	2,663	.
Total	21,054	17.1	2,065	5.9	13,800	5.8	5,307	2.9	3,350	.2	---	.	5,790	.9	51,366	.7
Provincial Total	123,000		35,000		239,000		186,000		2,027,000		3,948,000		684,000		7,242,000	
Unemployment Rate	6.1		x		4.8		5.1		4.1		2.5		4.6		3.3	
1971																
Primary	7,300	5.4	1,600	4.2	7,100	2.8	2,700	1.4	2,800	.1	---	.	2,200	.3	23,700	.3
Processing 1)	5,107	3.8	717	1.9	3,774	1.5	2,607	1.3	1,360	.1	---	.	1,769	.2	15,334	.2
2)	459	.3	72	.2	510	.2	269	.1	120	.	---	.	830	.1	2,260	.
Total	12,866	9.5	2,389	6.3	11,384	4.4	5,576	2.8	4,280	.2	---	.	4,799	.6	41,294	.5
Provincial Total	135,000		38,000		257,000		198,000		2,176,000		4,470,000		835,000		8,109,000	
Unemployment Rate	8.8		x		6.9		6.2		7.3		5.3		7.2		6.2	
1975																
Primary	5,000	3.3	1,600	3.7	7,000	2.4	11,500	5.0	2,500	.1	---	.	2,500	.3	30,100	.3
Processing 1)	3,878	2.5	459	1.1	3,665	1.2	2,122	.9	1,163	.	---	.	2,084	.2	13,371	.1
2)	466	.3	51	.1	689	.2	221	.1	202	.	---	.	967	.1	2,596	.
Total	9,344	6.2	2,110	4.9	11,354	3.9	13,843	6.0	3,865	.2	---	.	5,551	5.5	46,067	.5
Provincial Total	152,000		43,000		295,000		229,000		2,452,000		5,184,000		1,009,000		9,364,000	
Unemployment Rate	14.2		8.2		7.8		9.9		8.1		5.6		8.5		6.9	

Note: --- Less than 5.
. Less than .1%.
x not calculated.

Source: 1/ Statistics Canada Fisheries Statistics #24-201 - 24-212.
2/ Statistics Canada Manufacturing Industries of Canada: National and Provincial Areas #13-213.
3/ Statistics Canada Historical Labour Force Statistics #71-201.

1) Refers to production workers, and
2) Refers to salaried employees.

since the early 1970's, Newfoundland has been losing ground to Nova Scotia and New Brunswick. In 1961, an estimated 18% of persons employed in Newfoundland were employed in the primary and processing part of the sea fish system (Table III). This contribution decreased to 17.1% in 1966, to 9.5% in 1971 and finally to 6.2% in 1975. The major source of this decrease was in the primary sector where employment declined from 15,700 in 1961 to approximately 5,000 in 1975. This may be a result of capital-labour substitution or decreased output or some combination of the two. In contrast to the conditions in Newfoundland, employment in the primary and processing sectors of the sea fish system in the other provinces either decreased slightly or increased slightly during the period 1961-1975.

It is possible that the decline in employment in Newfoundland's primary and processing sectors of the sea fish system contributed substantially to the high level of unemployment in that province. Newfoundland had the highest unemployment rate (8.6%) in Canada in 1961 and maintained this dubious distinction through the census years 1966 and 1971. By 1975, it had escalated to an incredible 14.2% (Table III).

Wages and Salaries

The total wage bill to persons employed in the primary and processing sea fish sectors in 1975 amounted to $193 million, .2% of total wages and salaries paid in Canada (Table IV). Although the total amount has increased steadily, the contribution to total wages and salaries decreased from .3% in 1961 to .2% in 1975 (Table IV).

TABLE IV

Wages and Salaries in Canada's Primary and Processing Sea Fish Industries, by Region:
For the Periods 1961, 1966, 1971 and 1975

(Current $000's and as a % of the Provincial Total)

Wages and Salaries Paid in the Primary and Processing Sea Fish Industries	Newfoundland $000's	%	P.E.I. $000's	%	Nova Scotia $000's	%	New Brunswick $000's	%	Quebec $000's	%	Central Canada $000's	%	British Columbia $000's	%	Canada $000's	%
1961																
Primary[1]	3,423	1.2	556	1.1	8,661	1.6	2,031	.5	1,136	.	---	.	8,441	.4	24,248	.4
Processing[2]	5,271	1.8	497	1.0	9,164	1.7	2,115	1.0	1,504	.	---	.	10,224	.5	30,775	.2
Total: Fish	8,694	3.2	1,053	2.1	17,825	3.3	6,146	1.5	2,640	.1	---	.	18,665	.9	55,023	.3
Regional Total[3]	274,800		49,200		546,000		400,800		4,883,600		10,785,600		1,994,400		18,884,400	
Avg. Wage Rate[4]	2,640		1,490		2,380		2,370		2,840		3,120		3,620		3,020	
1966																
Primary	6,096	1.4	805	1.1	15,443	2.1	2,943	.5	1,817	.	---	.	13,209	.4	40,313	.1
Processing	11,409	2.6	982	1.3	15,689	2.1	66,221	1.1	3,008	.	---	.	18,783	.6	56,092	.2
Total: Fish	17,505	3.9	1,789	2.4	31,132	4.3	9,164	1.6	4,825	.1	---	.	31,992	1.0	96,405	.3
Regional Total	446,900		74,400		730,800		589,800		7,517,200		15,643,400		3,122,600		28.125,100	
Avg. Wage Rate	3,630		2,130		3,060		3,170		3,710		3,960		4,570		3,680	
1971																
Primary	8,372	.8	1,271	1.0	18,384	2.6	4,268	.3	2,595	.	---	.	12,643	.2	47,533	.1
Processing	19,721	2.0	2,990	2.3	17,854	2.1	9,794	.8	5,663	.	---	.	18,187	.3	74,209	.2
Total: Fish	28,093	2.8	4,261	3.3	36,238	5.1	14,062	1.1	8,258	.1	---	.	30,830	.6	121,742	.3
Regional Total	997,000		128,000		715,000		1,235,000		27,892,000		5,352,000		5,352,000		48,615,000	
Avg. Wage Rate	7,390		3,370		2,782		6,240		5,650		6,240		6,410		6,000	
1975																
Primary	5,128	.4	1,312	.5	27,802	1.2	6,297	.3	3,240	.	---	.	17,473	.2	61,252	.1
Processing	30,833	2.3	3,239	1.3	32,537	1.4	15,889	.8	9,084	.	---	.	40,225	.4	131,807	.2
Total: Fish	35,961	2.7	4,551	1.9	60,339	2.6	22,186	1.2	12,324	.1	---	.	57,698	.6	193,059	.2
Regional Total	1,325,000		243,000		2,283,000		1,883,000		21,787,000		49,250,000		10,200,000		86,971,000	
Avg. Wage Rate	8,700		5,651		7,740		8,220		8,890		9,500		10,110		9,290	

Note: --- Less than $1,000.
. Less than .1%.

Source: 1/ Statistics Canada, Labour Income Unit, Fishing Wages and Salaries by Province.
2/ Statistics Canada, Manufacturing Industries of Canada: National and Provincial Areas #21-203.
3/ Statistics Canada, Canadian Statistical Review #11-003.
4/ Avg. Wage Rate = regional total wage and salary bill divided by the number employed.

At the regional level, British Columbia and Nova Scotia have traditionally been the provinces exhibiting the largest wage bills paid in the primary and processing sectors of the sea fish system (Table IV). In terms of the relative contribution to wages and salaries paid in each region, the primary and processing sectors of the sea fish system are traditionally more important in the Atlantic provinces (Table IV) than in Quebec and British Columbia.

If total wages and salaries paid in a particular year in a particular region are divided by the average number of persons employed in that year and region, an estimate of the average yearly wage rate is obtained for each region (Table IV). In general, the average yearly wage rate of persons employed in the Atlantic provinces is substantially lower than that of Central Canada and British Columbia (Table IV).

International Commodity Trade

Canada exports significantly more sea fish than it imports. According to F.A.O. statistics, in 1975 and 1976, Canada ranked fourth in the world in terms of net exports of fish products,[9] achieving a net export position of \$305 million in 1975 and \$367 million in 1976.[10] According to Statistics Canada, in 1976, exports of sea fish from Newfoundland accounted for 25% of that province's commodity exports; sea fish exports from Nova Scotia accounted for 19% of that province's commodity exports; sea fish

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[9] For both periods the top three countries were, in order of the largest to smallest value of net exports: Norway, Republic of Korea, and Denmark.

[10] F.A.O. Production Yearbook (1976), Vol. 30, p. 85.

exports from Nova Scotia accounted for 19% of that province's commodity exports; sea fish exports from Prince Edward Island accounted for 19% of that province's commodity exports and sea fish exports from New Brunswick accounted for 5% of that province's commodity exports.[11] In Quebec and British Columbia, sea fish exports accounted for less than 1% of commodity exports.[12]

Summary

In terms of output, employment, wages and salaries, and international commodity trade, the sea fish system is relatively more important in the regional economies on Canada's east coast than it is in other area in Canada. In addition, the unemployment rate has been high and the average yearly wage rate of persons employed has been low in the Atlantic provinces as compared to the national average.

Given that the Canadian government has assumed control of the maximum amount of catch of sea fish within the 200 mile limit, government policy may have a significant impact on economic activity in the Atlantic provinces.

In view of the fact that this thesis deals with only a part of the sea fish system's primary sector on the Atlantic coast, the Atlantic groundfish industry will be briefly outlined in terms of its importance to fishermen on the Atlantic coast and the major production techniques employed in extracting groundfish from the ocean on the Atlantic coast.

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[11] Statistics Canada, Exports by Countries, #65-003 (Jan-Dec, 1976).

[12] Ibid.

The Atlantic Groundfish Industry

Essentially, there are three major groups of species of sea fish caught on the Atlantic coast: groundfish, pelagic and estuarial, and molluscs and crustaceans.[13] The Atlantic groundfish industry was selected because:

(i) it has traditionally been the most important in terms of the value of catch (Figure II),

(ii) stocks of groundfish have been badly depleted over the last decade (Figure III),

(iii) government projections indicate that the total allowable catch (T.A.C.) of major groundfish will increase substantially between 1976 and the mid-1980's (Figure III).

With the total allowable catch of groundfish expanding into the mid-1980's, what will the effect on employment in the groundfish industry on the Atlantic coast be? What happens to employment depends on a number of factors which will be integrated in the next chapter when the theoretical foundations of the economic model of the Atlantic groundfish industry are put forth.

One of the prime factors which will influence what happens to employment in the Atlantic groundfish industry enters the analysis under the heading of "capital". Capital investment in the Atlantic groundfish primary industry is generally directed into vessels or gear. Most of the groundfish landed on the Atlantic coast are caught by longliners, stern or side draggers, or stern or side trawlers.

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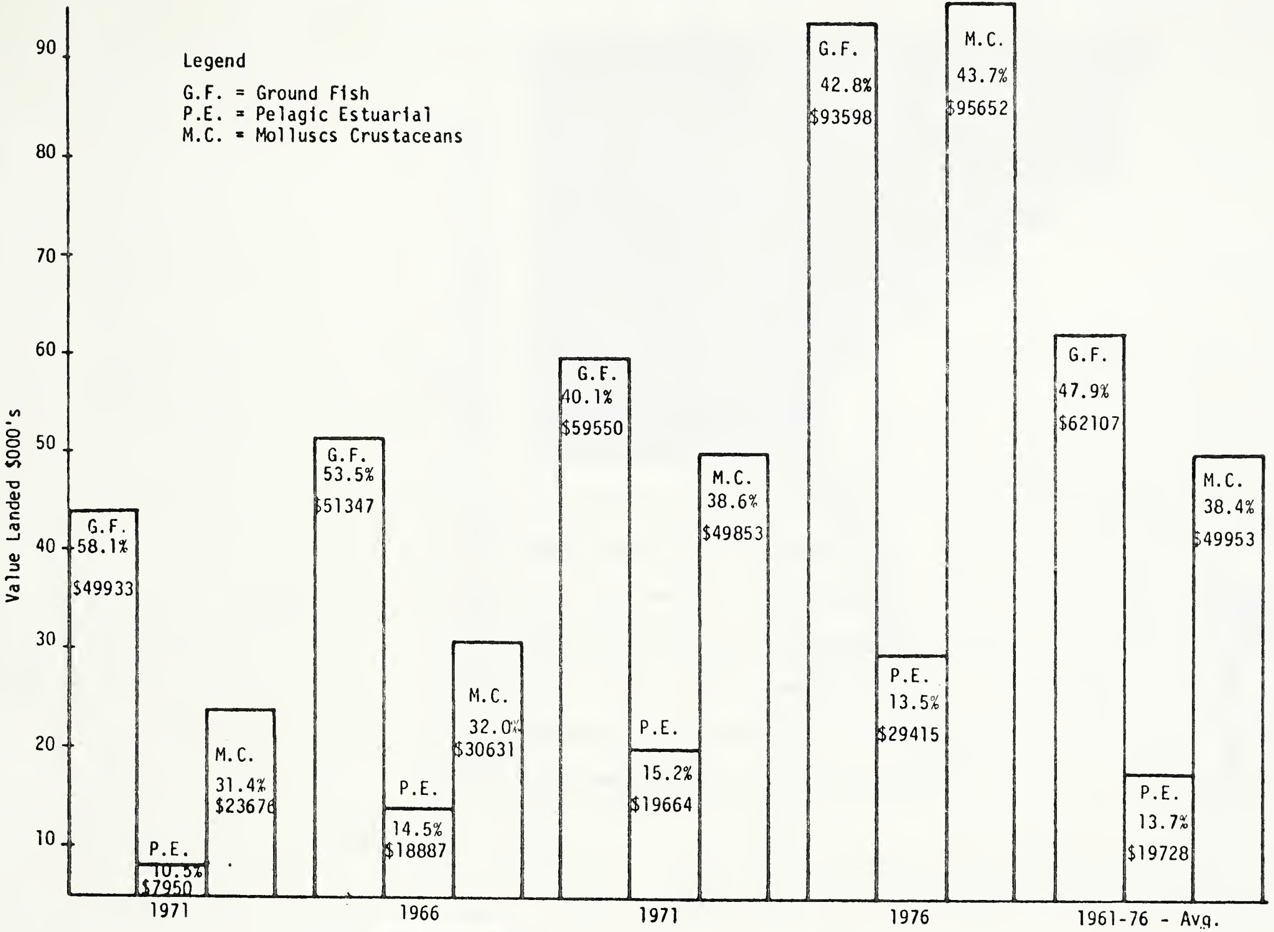
[13] A complete breakdown by species is provided in Appendix 1

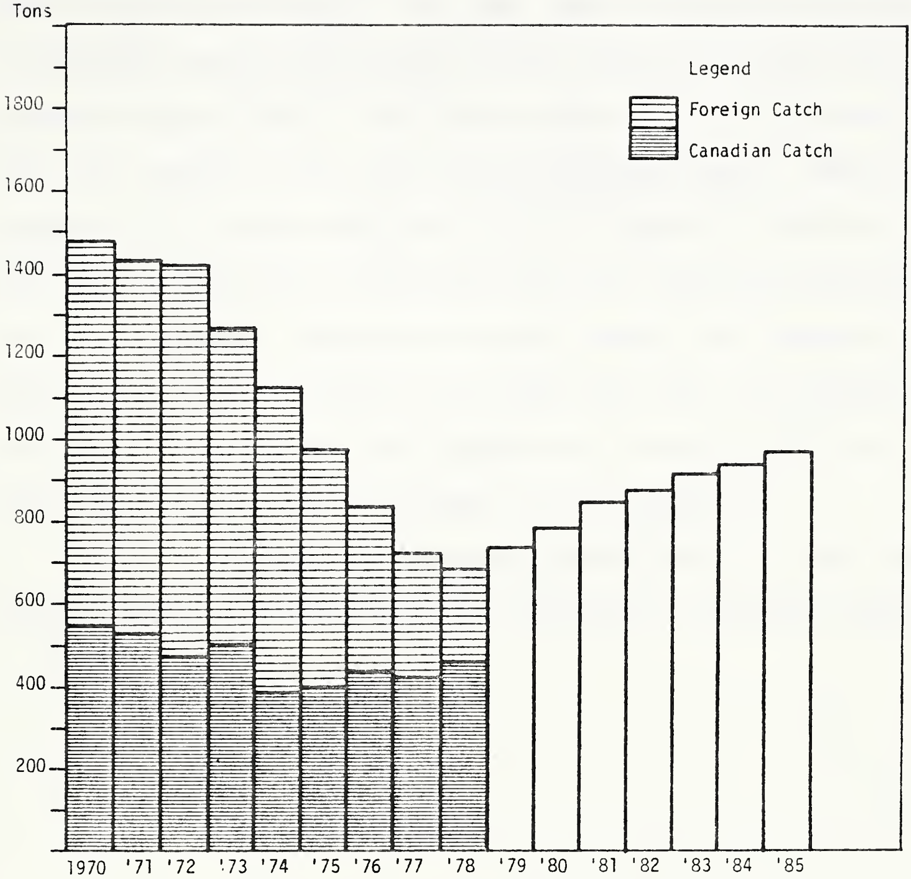
FIGURE II
Value of Catch of Major Species of Sea Fish on the Atlantic Coast by Canadian Fishermen 1961, 1966, 1971 and 1976.



SOURCE: Statistics Canada "Canadian Fisheries Statistics" #24-201.

FIGURE III

Total and Canadian Catches of Major[1] Ground Fish Species 1970-1976 With Total Allowable Catches for 1977 and 1978 and Projected Total Allowable Catches to 1985 (All Within the 200 Mile Limit)



SOURCE: Atlantic Coast Resource Prospects - 1978 to 1985, Fisheries and Marine Service, Department of Fisheries and the Environment, Ottawa, Ont. K1A 0E6

NOTE: [1] Major Species : Cod, Redfish, Haddock, American Plaice, Witch, Greenland, Halibut, Yellowtail and Pollock.

According to sample data covering the period 1962-1976, longliner vessels generally ranged from 30 to 90 feet but are most commonly in the 40 to 60 foot range.[14] The gear used in longlining consists of a length of strong rope to which shorter lines with baited hooks are attached (Figure IV(a)). The longline is set out on the ocean floor and later hauled in with the aid of a powered winch. Trawlers and draggers use a funnel-shaped net which is closed at the narrow end. The mouth of the net is usually kept open by iron-shod wooden doors. The only conceptual difference between trawlers and draggers is the size of the vessels, draggers being under 100 feet and trawlers being over 100 feet in length. Most draggers are in the 60 to 90 foot range while most trawlers range in length from 120 to 150 feet.

With this background information established, the next chapter builds a demand-for-labour model for the Atlantic groundfish industry.

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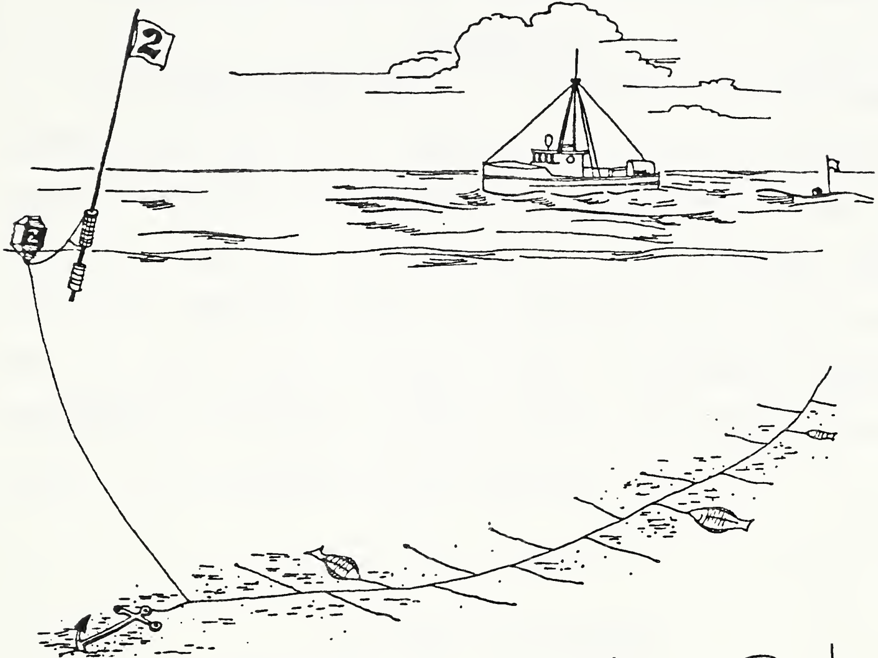
[14] J. Proskie and J.P. Cherron, Cost and Earnings of Selected Fishing Enterprises (1962-1976). Department of Fisheries and the Environment.

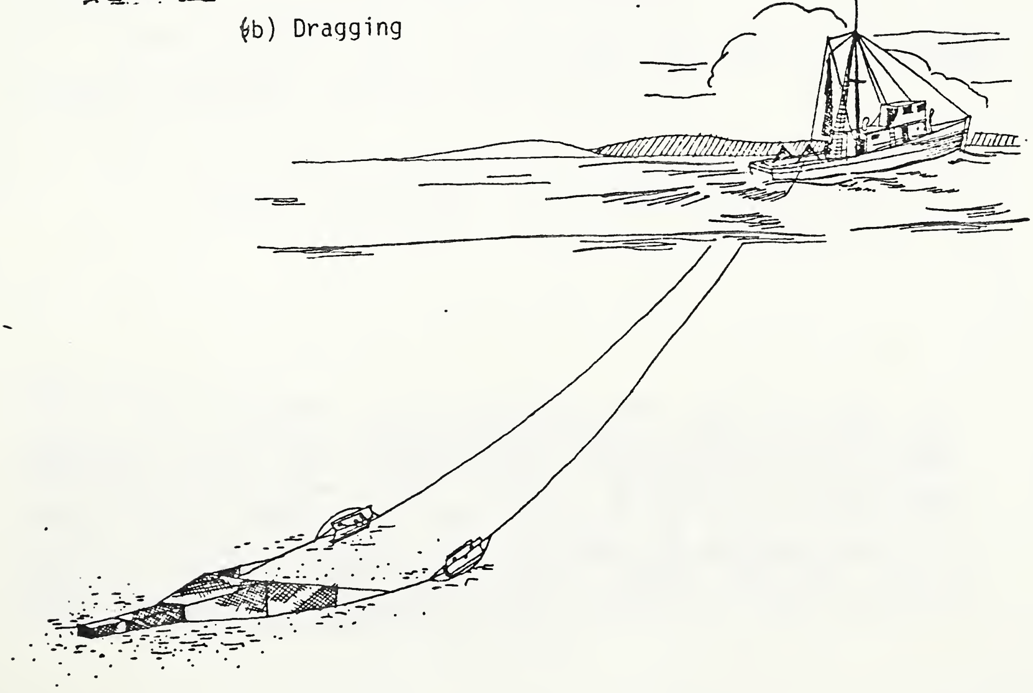
FIGURE IV

Two Major Techniques Employed In Extracting Groundfish From The Atlantic Ocean

(a) Longlining



(b) Dragging



CHAPTER III

THE DEMAND FOR LABOUR AS DERIVED FROM THE CONSTANT ELASTICITY OF SUBSTITUTION (C.E.S.) PRODUCTION FUNCTION[15]

Introduction

The object of this chapter is to briefly review the theory of production with the aim of determing just how it can be utilized to derive a demand-for-labour model that can be related to the Atlantic groundfish industry. The properties of a particular type of neoclassical production function are examined and are then included as part of a more general economic model. The chapter concludes by statistically specifying an economic model and providing theoretical evidence of the properties of the estimates.

The Theory of Production

Given a certain state of technology, the theory of production attempts to provide a systematic explanation of:

(i) how scarce resources are allocated amongst different outputs (the marginal rate of technical sustitution rule),

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[15] The ideas presented in this chapter draw primarily upon four sources: W. Nicholson, Microeconomic Theory: Basic Principles and Extensions (1972), particularly chapter 20 "The Concept of Economic Efficiency", The Dryden Press; Henderson and Quandt, Microeconomic Theory (1971), chapter III "The Theory of the Firm," McGraw-Hill Co.; M. Brown, On the Theory and Measurement of Technical Change in Production (1966), Cambridge University Press, and K.F. Wallis Topics in Applied Econometrics (1973), Chapter 2 "The Production Function," Grey-Mills Publishing Limited.

(ii) which combination of outputs can be produced from a given amount of inputs (the rate of product transformation rule), and

(iii) how much of those outputs can be produced (the marginal physical product rule).

The production function is a general concept which gives mathematical expression to the relationships (a) between the quantities of inputs employed in the production process of a firm, (b) between the quantities of outputs produced in the production process of a firm given a certain amount of inputs, and (c) between the quantities of outputs which a firm can generate from a certain amount of inputs. Ideally, the production function contains no economic magnitudes; its purpose is to act as a technical constraint in an economic system (characterizing the efficient production possibilities open to the entrepreneur in transforming inputs into outputs).

An intersting defence of the production concept has been made by M. Brown:

> The objection is raised that the production function is a fiction....Since the production function is indirectly related to the physical-technical aspects of production, it is not directly measureable and since it is foreign to the world of commond sense, it is a fiction fabricated by the marginalist economist.
>
> In one sense this argument is valid: the production function is fabricated by economists... yet...the employment of production functions can be justified simply on the grounds that it produces highly useful and verifiable hypotheses....The abstractness of the production function concept is precisely its source of value; it enables economists to analyze a wide variety of

> problems, for example, the determination of relative income shares, the factors effecting economic growth and the nature of technological unemployment.[16]

Based on this line of reasoning, the concept of the production function is developed and used to derive a demand for labour function in the Atlantic groundfish industry.

The Neoclassical Production Function

Properties of the neoclassical production function are that it is "continuous, single valued and at least twice differentiable."[17] As stated previously, the production function summarizes the efficient production possibilities open to the entrepreneur and so, noting that the function is single valued, there is only one maximum amount of output corresponding to each combination of the relevant factors of production. To simplify matters, the production function may be written conceptually as: $Q = F(K,L)$; where Q is expressed, in flow terms,[18] as the quantity of output, and K and L are flows of services from stocks of capital and labour, respectively, required to generate the flow of output.

Essentially, there are four types of abstract technology which are definable in terms of the concept of the production function. They are:

(i) the elasticity of factor substitution,
(ii) capital intensity,
(iii) technical efficiency, and
(iv) returns to scale.

---

[16] Ibid.

[17] K.F. Wallis, Topics in Applied Econometrics (1973), p. 27.

[18] This expresses the fact that it is measured over time.

The constant elasticity of substitution (C.E.S.) production function, attributable to Arrow, Chenery, Minhas and Solow,[19] can be fitted using data, and the abstract technology underlying current production techniques can then be determined.

Consider the C.E.S. production function:

$$Q = \gamma\{\delta K^{-\rho} + (1-\delta)L^{-\rho}\}^{-\nu/\rho}, \ (\delta > 0), \ (0<\delta<1), \ (\rho > -1), \ (\nu > 0), \quad (1)$$

Time scripts have been dropped since the relationship is postulated over one unit of time only and there are no dynamic properties posed. It can be shown that γ represents "technical efficiency", δ is referred to as "capital intensity", ρ is referred to as the "substitution" parameter and ν is the "returns to scale" parameter.

The Elasticity of Factor Substitution

We begin with this parameter since once this is established, the other parameters are easily defined. The elasticity of factor substitution is generally written as σ and is equivalent to $1/(1+\rho)$. It is defined, technically, as the percentage change in factor proportions (K/L) given a 1 percent change in the marginal rate of technical substitution (MRTS).

The MRTS is defined as the absolute slope of an isoquant, thus indicating the rate at which one factor is substituted for another. It is generally assumed that the MRTS diminishes as substitution proceeds along an isoquant (for example, more labour is substituted for capital, for each "unit" of capital given up

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[19] K.J. Arrow, H.B. Chenery, B.S. Minhas and R.M. Solow, "Capital-Labour Substitution and Economic Efficiency", Review of Economics and Statistics (1961)

relatively more and more labour is required to displace the capital in order to keep output constant). Since the MRTS. can be defined in terms of the ratio of the marginal products of capital and labour,[20] their marginal physical products will be derived in the C.E.S. production function, their ratio taken and the MRTS will be found. Re-writing Eq. 1:

$$Q^{-\rho/\nu} = \gamma^{-\rho/\nu}\{\delta K^{-\rho} + (1-\delta)L^{-\rho}\} \tag{2}$$

and so taking the differentials with respect to capital and then labour, respectively,

$$-\rho/\nu Q^{-\rho/\nu-1}\frac{\partial Q}{\partial K} = -\rho\gamma^{-\rho/\nu}\delta K^{-\rho-1} \text{ or } \frac{\partial Q}{\partial K} = MPK = \nu\delta\gamma^{-\rho/\nu}\frac{Q^{1+\rho/\nu}}{K^{1+\rho}} \tag{3}$$

and

$$-\rho/\nu Q^{-\rho/\nu-1}\frac{\partial Q}{\partial L} = -\rho\gamma^{-\rho/\nu}(1-\delta)^{-\rho-1} \text{ or } \frac{\partial Q}{\partial L} = MPL = \nu(1-\delta)\gamma^{-\rho/\nu}\frac{Q^{1+\rho/\nu}}{L^{1+\rho}} \tag{4}$$

Thus the MRTS, defined as MPL/MPK is equal to:

$$MRTS = \frac{\nu(1-\delta)\gamma^{-\rho/\nu}\quad Q^{1+\rho/\nu}L^{1+\rho}}{\nu\delta\gamma^{-\rho/\nu}\quad Q^{1+\rho/\nu}K^{1+\rho}} = \frac{1-\delta}{\delta}\;\frac{K^{1+\rho}}{L} \tag{5}$$

---

[20] If Q=F(K,L) is the general form of the production function,

$\frac{\partial Q}{\partial K}$ = the marginal physical product of capital (MPK)

and $\frac{\partial Q}{\partial L}$ = the marginal physical product of labour (MPL),

then taking the total differential of the production function produces:

$dQ = 0 = \frac{\partial Q}{\partial K} \times dK + \frac{\partial Q}{\partial L} - dL$ and the MRTS (as defined)

$= -\frac{dK}{dL} = \frac{MPL}{MPK}$

or

$$\frac{K}{L} = \left(\frac{\delta}{1-\delta}\right)^{1/1+\rho} \text{MRTS}^{1/1+\rho} \quad \text{which upon taking logs:} \quad (6)$$

$$\log (K/L) = 1/1+\rho \log \{\delta/1-\delta\} + 1/1+\rho \log \text{MRTS} \qquad (7)$$

Therefore, a 1 percent change in the MRTS results in a $(1/1+\rho)$% change in the factor proportions which is precisely the definition of the elasticity of factor substitution. For a particular production process, it measures the ease with which capital, say machine hours, and labour, say man hours, are substitutable (Figure V); the larger σ, ($\sigma_2 < \sigma_1$, in Figure V), the greater the change in $(\frac{K}{L})$ given a certain change in the MRTS and so the greater the ease of substitution between capital and labour.

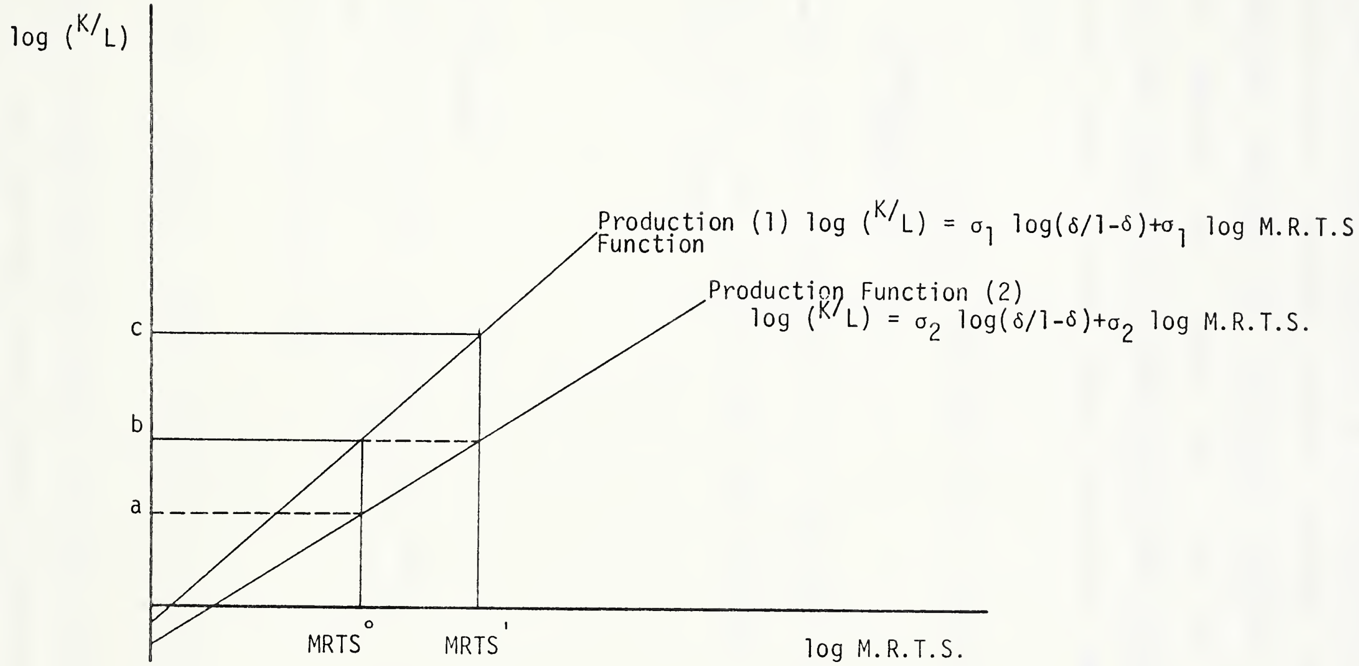
Capital Intensity

The capital intensity of an abstract technology is defined as the relative amount of capital to labour, say machine hours to labour hours, that is employed for any given MRTS. This is expressed diagrammatically in Figure VI. If we take two production techniques, such as (1) and (2) in Figure VI, with the same elasticity of substitution, then, for a given MRTS, say at (a), the production technique employing the most capital to labour

$(\log (\frac{K}{L})_1 > \log (\frac{K}{L})_2$ in Figure VI)

FIGURE V

Differences In Elasticity of Factor Substitution Between Two Production Functions


log $(^K/_L)$
c
b
a
Production Function (1) $\log(^K/_L) = \sigma_1 \log(\delta/1-\delta)+\sigma_1 \log$ M.R.T.S
Production Function (2)
$\log(^K/_L) = \sigma_2 \log(\delta/1-\delta)+\sigma_2 \log$ M.R.T.S.
MRTS°
MRTS'
log M.R.T.S.

indicates that its abstract technology is relatively capital intensive as compared to that of the other production technique. Thus, in this case, production technique (1) is capital intensive relative to production technique (2). Note that even if the slopes coefficients--the elasticities of substitution--are different for the two techniques, capital intensity may be estimated for each production technique as:

$$\log \left(\frac{K}{L}\right) = \beta_0 + \beta_1 \log \text{MRTS} \quad \text{where } \text{Log}\,(\delta/1-\delta) = \beta_0/\beta_1 \qquad (8)$$

$$\text{or} \qquad = \frac{\text{antilog}\,(\beta_0/\beta_1)}{1 + \text{antilog}\,(\beta_0/\beta_1)}$$

However, capital intensity is not invarient to units of measurement and so care must be made when drawing comparisons between different studies.

Technical Efficiency

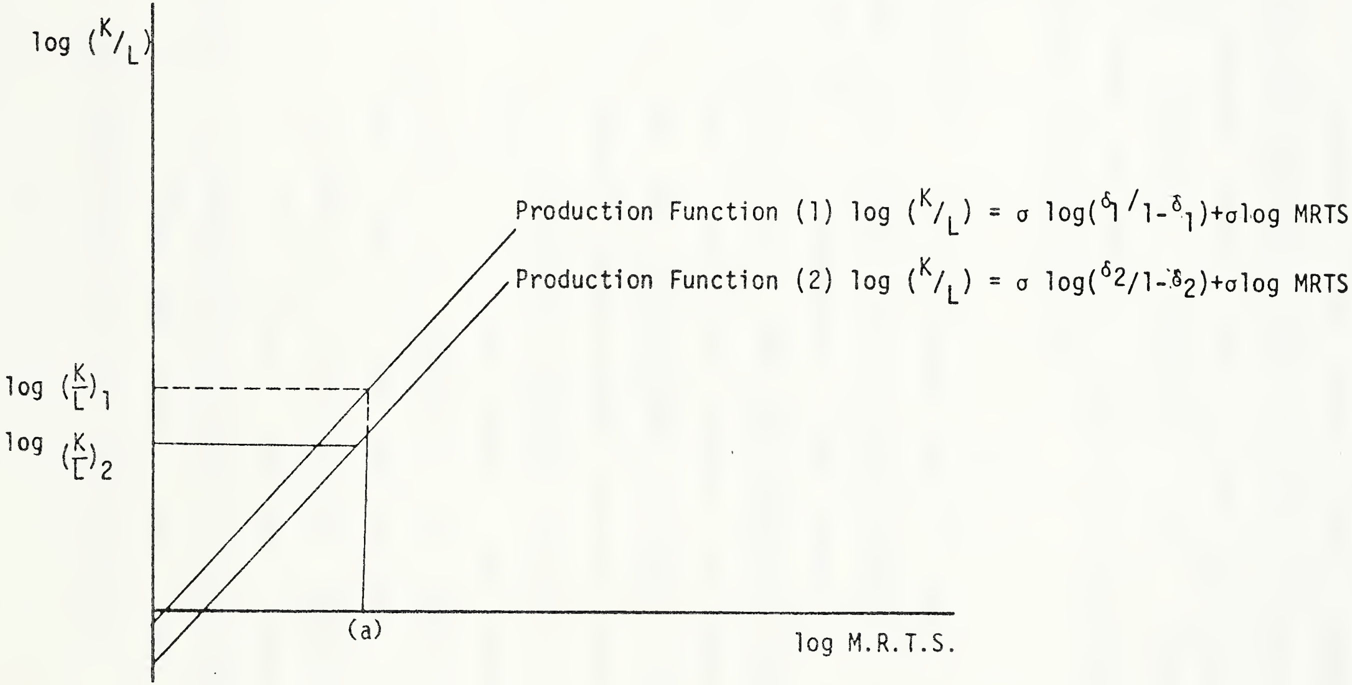
Technical efficiency is defined as the amount of output that can be generated given a certain amount of capital and labour. Writing the production function as:

$$\log Q = \log \gamma + \nu \log Z, \text{ where } Z = \{K^{-\rho} + (1 - \delta)L\}^{-1/\rho} \qquad (9)$$

then, given a certain amount of capital and labour, ceteris paribus, the amount of output generated will be greater as technical efficiency (the intercept term) increases.

FIGURE VI

Differences in Capital Intensity Between Two Production Functions



If we examine two production techniques, as in Figure VII, then for a given level of capital and labour and σ and δ, or equivalently, for a given Z, say Z^0, and for a given return to scale technology, the technique generating the greater level of output is said to be technically more efficient. In Figure VII, given the same returns to scale, at Z^0 production technique (1) generates more output than technique (2) ($\log Q_1 > \log Q_2$) and so technique (1) is technically more efficient than (2).

Returns to Scale

This is defined as the proportional change in output given proportional change in all inputs. It may be that returns to scale are increasing, constant, or decreasing. If the returns to scale parameter, (ν), is grater than 1, then the production function exhibits increasing returns to scale—a 1% increase in all factors of production results in more than a 1% increase in output. If ν is equal to 1, then the production function exhibits constant returns to scale--a 1% increase in all factors of production results in a 1% increase in output. Finally, if ν is less than 1, then decreasing returns are exhibited--given a 1% increase in all factors of production, output increases by less than 1%. From equation (9), if capital and labour are increased by a certain percent, then output will increase by ν percent. The effects of different returns to scale, ceteris paribus, are diagrammatically depicted in Figure VIII. In this figure, it is evident that given a unit change in $\log Z$ (Z_0 to Z_1), the responsiveness of output will be greater, the larger ν.

FIGURE VII

Differences in Technical Efficiency
Between Two Production Functions

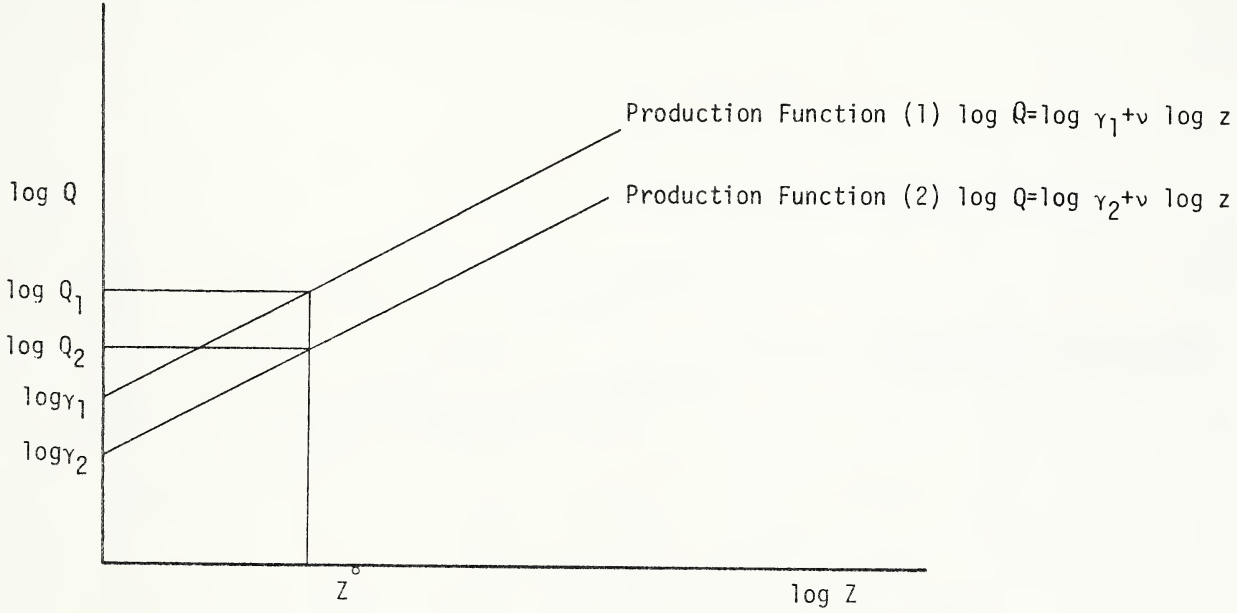
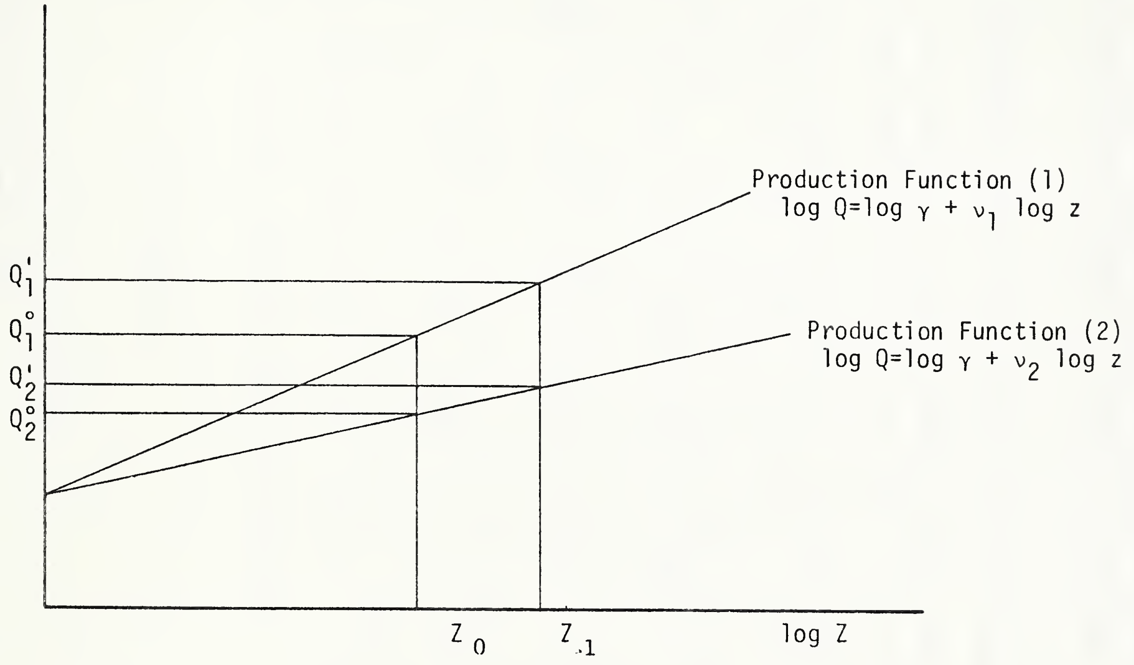


FIGURE VIII

Differences in Returns to Scale Between
Two Production Functions



Having discussed the technical properties of the C.E.S. production function, an economic model of the Atlantic groundfish industry will be established and the production function will be embedded in the economic model as a technical constraint.

An Economic Model of the Atlantic Groundfish Industry

In the Atlantic groundfish industry, output may be viewed as exogenous, the physical catch in the next time period ultimately being limited by the amount of stock left in the ocean after the present fishing period and the amount of reproduction which takes place between periods. In the short run (less than one fishing season), firms may initially seek to expand output by adding more capital and labour. However, whether their bid to do so is, or is not successful, depends upon the state of their technology compared to other firms and the existing resources in the ocean. Over the course of the fishing season, it is argued that firms engaged in extracting seafish have sufficient time to react to the output conditions imposed upon them by biological conditions and so act as cost minimizers. Being in a cost minimization framework, one begins with the Lagrangian:

a) $\zeta = TC + \lambda\{Q - F(K,L)\}$ (10a)

or

b) $\zeta = W \cdot L + r \cdot K + \lambda\{Q - F(K,L)\}$ (10b)

where W = the wage rate
L = man hours
r = cost of capital
K = units of capital.

For a given level of output, costs are minimized by differentiating with respect to L, K and λ, setting the derivatives equal to zero and checking that the second derivatives with respect to L and K are positive.

Thus: $$\frac{\partial \zeta}{\partial L} = W - \lambda \, MPL = 0 \tag{10c}$$

$$\frac{\partial \zeta}{\partial K} = r - \lambda \, MPK = 0 \tag{10d}$$

and $$\frac{\partial \zeta}{\partial \lambda} = Q - F(K,L) \tag{10e}$$

Setting (10e) equal to zero ensures that output level Q is attained. Taking the ratio of the marginal products in (10c) and (10d), $\frac{MPL}{MPK} = \frac{w}{r}$. Thus, the equation of the marginal rate of technical subsitution, or the ratio of the marginal products to the factor price ratio, yields the cost minimizing technique. Hence, from equation (6), cost minimization in the context of the C.E.S. production function is obtained by replacing the marginal rate of technical substitution to the factor price ratio:

$$\frac{K}{L} = (\delta/1 - \delta)^{\sigma} \left(\frac{w}{r}\right)^{\sigma} \tag{11}$$

From (11) $K = L \{ (\delta/1-\delta) (\frac{w}{r})^{\sigma} \}$

Substituting (11) into (2)

$$\left(\frac{Q}{\gamma}\right)^{-\rho/\nu} = \delta L \left\{ \left(\frac{\delta}{1-\delta}\right) \left(\frac{w}{r}\right)^{\sigma} \right\}^{-\rho} + (1-\delta) L^{-\rho} \tag{12a}$$

or

$$\left(\frac{Q}{\gamma}\right)^{-\rho/\nu} = L^{-\rho} (1-\delta) + \delta \left(\frac{\delta}{1-\delta}\right)^{\sigma} \left(\frac{w}{r}\right)^{\sigma} \tag{12b}$$

and so[21]

$$L = \left(\frac{Q}{\gamma}\right)^{1/\nu} w^{-\sigma} (1-\delta)^{\sigma} \{ \delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma} {}^{1/\rho} \tag{12c}$$

represents the cost minimizing amount of labour.

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[21] K.F. Wallis, *op. cit.*, p. 55

Rearranging 12 (c) and expressing it in logarithmic form:

$$\log L = -1/\nu \log \gamma + 1/\nu \log Q - \sigma \log \left(\frac{w}{1-\delta}\right) \qquad (13)$$

$$+ \sigma/1- \sigma \log \{ \delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma}$$

Thus, the major determinants of the demand for labour have been derived. Looking at the employment-wage relationship, ceteris paribus, a one percent increase in the wage rate results in a $(1-\frac{w}{Z} \left(\frac{1-\delta}{w}\right)^{\sigma})$ percent decrease[22] in the quantity of labour demanded. It is interesting to note that the difference in the C.E.S. employment-wage relationship and the Cobb Douglas employment-wage relationship, $(d \log L/d \log w = -\delta)$, is due to the fact that the Cobb Douglas production function imposes σ to be equal to 1. Thus, the C.E.S. specification adjusts for this possible bias in the case of $\sigma \neq 1$.

Alternatively, holding the wage rate and constant, what happens to the labour demand function if output or returns to scale change? This may best be explained in two steps. First, in Figure IX(a), the relationship between output and employment is depicted for three returns to scale technologies $(\nu_1 > \nu_2 > \nu_3)$. As was seen in equation (13), a 1% increase in the firm's output shifts the demand for labour out by $1/\nu$ percent.

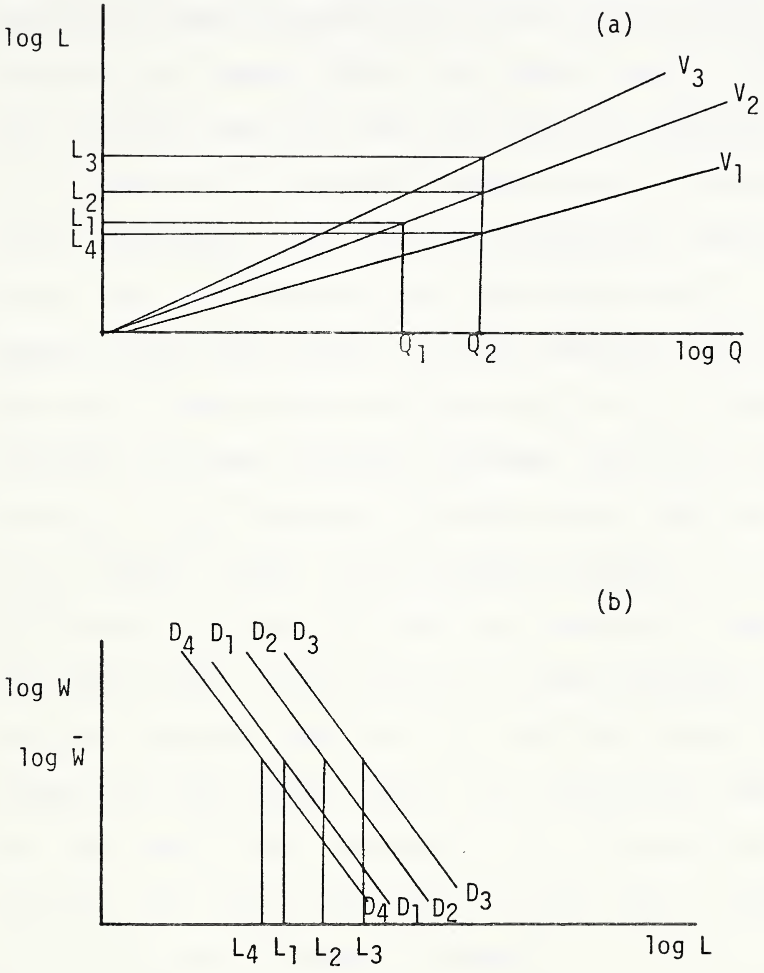
---

[22] $Z = (\delta^{\sigma} \cdot r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma})$

See Appendix II for the derivation of the demand function.

FIGURE IX

The Implications of a Change in Output or Returns to Scale on the Demand for Labour



Suppose that returns to scale technology is represented by ν_2 in Figure IX(a), then given an output increase from Q_1 to Q_2, the quantity of labour demanded will increase from L_1 to L_2. Similarly, in Figure IX(b), the demand function D^1D^1 will shift out to D^2D^2, where L_2 units of labour are demanded at wage rate $\bar{w}$. If, however, in the meantime there has been a change in returns to scale technology, then the output employment relationship, Figure IX(a), will be different than that depicted by ν_2. First, if we suppose that the returns to scale decrease, to say, ν_3 from ν_2, then for a given change in output, Q_1 to Q_2 in Figure IX(a), the quantity of labour demanded increases from L_1 to L_3 instead of just L_1 to L_2, Similarly, if Figure IX(b), this will be reflected in a greater shift in the demand function, say from D^1D^1 to D^3D^3 where L_3 units of labour are demanded at wage rate $\bar{w}$. On the other hand, if the returns to scale increased from ν_2 to ν_1, then the resulting shift could be sufficient enough that at the new output level Q_2 (Figure IX(a)), the quantity of labour demanded L_4 is less than it was originally (L_1). At wage rate $\bar{w}$, the demand function may shift from D^1D^1 to D^4D^4, as in Figure IX(b), so that only L_4 units of labour in demand.

In equation (13), it is seen that an increase in technical efficiency has exactly the opposite effect on the demand for labour that an increase in output has.

Statistical Model

If the economic model in equation (13) employed a properly specified production function, correctly specified the economic behaviour of entrepreneurs and if entrepreneurs themselves were operating in a perfectly competitive environment then equation 13 would be deterministic. However, the C.E.S. production function may only approximate the physical-technical constraints governing extraction, there may be other variables (perhaps non-economic) influencing entrepreneurial decisions, random behaviour may be exhibited on the part of entrepreneurs or there may be errors in the variables which appear as accounting data in the firm's books. All of these possibilities admit the presence of an error term.

Under the presumption that there are no errors in the variables, or at least that firms actually behave on the basis of the information they present in their accounting data, then the model depicted in equation 13 could be set up to test various hypotheses about the technology underlying the extraction process.

Thus, let us begin with the statistical specification of the demand for labour in the Atlantic groundfish industry:

$$\text{Log } L_i = \hat{\beta}_0 + \hat{\beta}_1 \log Q_i + \hat{\beta}_2 \log \left(\delta \left(\frac{1-\delta}{\delta}\right)^{1-\sigma} \left(\frac{r}{w}\right)_i^{1-\sigma} + 1-\delta\right) + Ui \tag{14}$$

$i = 1$ G = the number of representative vessels and U = the error term.

The usefulness of this function would, upon brief inspection, appear to be somewhat limited as direct estimates of all parameters cannot be obtained. However, recall the cost minimization equation. Entering the error term multiplicitively and then expressing it in logarithms, the error term enters the equation additively so the log-linear equation may be examined in terms of the classical linear model. The cost minimization equation is:

$$\text{Log }(K/L)_i = \hat{\sigma} \log (\delta/1-\delta) + \hat{\sigma} \log \left(\frac{w}{r}\right)_i + \hat{u}_i ; \quad i = 1 \quad G \qquad (15a)$$

u = the error term

or

$$\text{Log }(K/L)_i = \hat{T}_0 + \hat{T}_1 \text{ Log } \left(\frac{w}{r}\right)_i + \hat{u}_i \qquad (15b)$$

where $\hat{T}_0 = \hat{T}_1 \text{ Log } (\delta/1-\delta)$

so $= \dfrac{\text{antilog } (\hat{T}_0 / \hat{T}_1}{1+ \text{antilog } (\hat{T}_0 / \hat{T}_1)}$

Following the classical linear model:

$Y = X\hat{\beta} + U$,(16) it is generally acknowledged that: Y is a (T.1) vector of observation of the dependent variable; X is a (T.K) matrix of observation of the explanatory variables; $\hat{\beta}$ is a (K.1) vector of coefficients associated with X; and U is a (T.1) vector of disturbance term. Furthermore, it is assumed:

A_1) The model is linear in parameters

A_2) $E(U) = 0$

A_3) $E(UU^1) = u^2 I$ (implying homoscedasticity and nonautocorrelated error term

A_4) $E(XU) = 0$ (implying the explanatory variables are not correlated with the error terms)

A_5) X has full rank (implying multicollinearity is not perfect).

Under these assumptions, the estimates $\hat{\beta}$ are best linear and unbiased in the sense that they have the smallest variance in the class of linear unbiased estimates of β. In the context of

equation (15b), in order for $\hat{T}$ to be B.L.U.E., (1) the expected value of the error term must be zero, (2) the error term is homoscedastic, (3) the error term of one firm is not correlated with that of another, over time, (4) the factor price ratio is independent of the error term, and (5) the variables in the factor price ratio vector are not linear combination of the unit vector in the X matrix.

The objection may be raised that because fishermen are, technically, paid a portion of the value of the catch, the wage rate is endogenous. However, the argument raised to counter this objection follows the lines of reasoning that the wage rate is exogenous (a) because historically entry into the fishery has not been impeded institutionally or financially to any great extent and so the wage rate paid to fishermen has been regulated by the going wage rate in the Atlantic region for jobs requiring similar skill and effort and (b) because more recently more and more fishermen's wages are being determined through contracts.

If the classical linear assumptions hold, then the estimates $\{\hat{T}\}$ will be best linear unbiased estimates of $\{\hat{T}\}$. The classical linear assumptions will be examined in Chapter IV when the estimates are made and tests of hypotheses are performed.

Once estimates of $\hat{\sigma}$ and $\hat{\delta}$ have been obtained from equation (15), they may be inserted into equation (14) to obtain:

$$\text{Log } L_i = \hat{\beta}_0 + \hat{\beta}_1 \log Q_i + \hat{\hat{\beta}}_2 \log (\hat{\hat{\delta}} \; (\underline{1-\hat{\hat{\delta}}}\,))^{1-\hat{\hat{\sigma}}} (\frac{r}{w})_i^{1-\hat{\hat{\sigma}}} + 1-\hat{\hat{\delta}}\,) + \hat{U}i \tag{17}$$

where $\hat{\hat{\beta}}_2$ is restricted to equal $\hat{\delta}/(1-\hat{\delta})$

Also:

$$-\frac{(1)}{\nu}\log\hat{\gamma} = \hat{\beta}_0$$

$$\frac{(1)}{\nu} = \hat{\beta}_1$$

$$\log\hat{\gamma} = (\hat{\beta}_0/-\hat{\beta}_1)$$

What are the properties of the estimates $\hat{\delta}$, $\hat{\sigma}$, $\hat{\nu}$ and $\hat{\gamma}$. In equation (15) it was seen that $\hat{T}_1 = \sigma\log(\delta/(1-\delta))$. If the classical linear assumptions hold, $\hat{T}_1$ will be the best linear unbiased estimate of σ and $\hat{T}_0$ will be the best linear unbiased estimate of σ $\log(\delta/1-\delta)$, or $\hat{T}_0/\hat{T}_1$ will be the best linear unbiased estimate of $\log(\delta/1-\sigma)$. Unfortunately, antilog $(\hat{T}_0/\hat{T}_1)/(1+$ antilog $\hat{T}_0/\hat{T}_1)$ does not yield the best linear unbiased estimate of δ since the expectation of a non-linear function is in general not the non-linear function of the expectation. Goldberger shows this in general terms using the Taylor's series expansion about EX and dropping higher order terms:

$$E\ (\text{antilog } X) = \text{antilog } E(X) + (X-E(X))\ \text{antilog } X/X = E(X) +$$

$$(X-E(X))^2\ \text{antilog } X/X = E(X) = \text{antilog } EX\ (1+\frac{u}{2}x)$$

where $E(X-EX) - 0$ and $E(X-EX)^2 = u_x^2$

For small samples, this indicates upward bias, however, as $n\to\infty$ the bias approaches zero since the variance (estimated by $u^2/T-K$ approaches zero.

In equation form, antilog $\lim_{n\to\infty}$ EX $(1+\frac{u^2}{2}x)$ antilog EX, so E (antilog X) is asymptotically equivalent to antilog E(X). In the context of equation (15), Wallis has indicated that:

antilog ($\hat{T}_0$ / $\hat{T}_1$)/(1+ antilog $\frac{\hat{T}_0}{\hat{T}_1}$) yields a consistent estimate of δ[23]. The variance of σ will be equal to the variance of $\hat{T}_1$. Kmenta[24] has shown if $\hat{a} = f(\beta_1, \dots \beta K)$, the large sample variance of $\hat{a}$ can be approximated as:

$$\text{Var}(\hat{a}) = \sum_{k=1}^{K} \{ \frac{\partial f}{\partial \hat{\beta}_k}^{2} \text{Var}(\hat{\beta}_k) + 2 \sum_{j<k}^{K} \frac{\partial f}{\partial \hat{\beta}_j} \cdot \frac{\partial f}{\partial \hat{\beta}_k} \text{cov}(\hat{\beta}_j \hat{\beta}_k)$$

$$j,k = 1 \dots K,\ j < k$$

Since log ($\delta/1-\delta$) = ($\hat{T}_0/\hat{T}_1$), and the (consistent) estimate of $\delta/1^{-\delta}$ is antilog ($\hat{T}_0 / \hat{T}_1$),[25] then the large sample variance of ($\delta/1-\delta$) may be approximated as antilog:

$$\frac{1}{\hat{T}_1} \text{Var}(\hat{T}_0) + \{ \frac{-\hat{T}_0}{\hat{T}_1^{2}} \}^2 \text{Var}(\hat{T}_1) + 2 \frac{1}{\hat{T}_1} \cdot \frac{-\hat{T}_0}{\hat{T}_1^{2}} \text{cov}(\hat{T}_0 \hat{T}_1)$$

From equation (15), if we let $(X^1X)^{-1} = \begin{matrix} a_{11} & a_{12} \\ a_{12} & a_{22} \end{matrix}$[26] and $\sigma^2 = \hat{\sigma}^2/T-K$,

$$\text{Var}(\delta/1-\delta) = \{\frac{1}{\hat{T}_1}\}^2 \cdot \frac{\sigma^2}{T-K} a_{11} + \{ \frac{-\hat{T}_0}{\hat{T}_1^{2}} \cdot \frac{\hat{\sigma}^2}{T-K} a_{22} + 2\{\frac{1}{\hat{T}_1} \cdot \frac{-\hat{T}_0}{\hat{T}_1^{2}}\} \cdot \frac{\hat{\sigma}^2}{T-K} a_{12}$$

Having obtained the estimates σ and δ and the variances of σ and ($\hat{\delta}/1-\hat{\delta}$), what are the properties of the estimates of $\hat{\sigma}$ and $\hat{\nu}$ and what are their variances in the demand function? One of the classical linear assumptions requires that the explanatory variables be independent of the error term. In the demand function, this requires that the level of output, the wage rate, the interest rate

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[23] Wallis, op. cit., p. 59

[24] J. Kmenta, Elements of Econometrics (1971), p.444

[25] $\lim_{n \to \infty} E(\text{antilog } \hat{T}_0 / \hat{T}_1) \quad \text{antilog} \lim_{n \to \infty} E(\hat{T}_0 / \hat{T}_1)$

[26] $(X^1X)^{-1}$ is symetric so $a_{12} = a_{21}$

and the error term from equation (15) (sometimes referred to as the commercial efficiency disturbance term--the over or under achievement of the optimal factor proportions given the factor price ratio) be independent of the error term in the demand function. If this and the other classical assumptions hold true, then $\hat{\nu}$ and $\hat{\gamma}$ will provide consistent estimates of ν and γ .

Recall in equation (17) $\hat{\beta}_1 = \frac{1}{\nu}$ and $\frac{\hat{\beta}_0}{\hat{\beta}_1} = \log \gamma$. In this case then, $E(\hat{\beta}) = E(\frac{1}{\nu})$ and $E(\nu) = E(\frac{1}{\hat{\beta}})$. The question then arises, does $E(\frac{1}{\hat{\beta}}) = \frac{1}{E(\hat{\beta})}$.

In general, the two are not equal.[27]

However, noting that a consistent estimator is defined as

$$\lim \Pr(\mid \hat{\beta}^{(n)} - \beta \mid < \varepsilon) = 1, \text{ or } \operatorname{plim} \hat{\beta}^{(n)} = \beta$$ [28]

(which means that the estimate $\hat{\beta}^{(n)}$ converges in probability to β), it can be shown that $(\operatorname{plim} \hat{\beta}^{-1}) = \beta^{-1}$

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[27] Wallis, K.F. Applied Econometrics.

[28] J.J. Johnston, Econometric Methods (1972), p.271

Proof: Given that plim $(A^{-1}) = (\text{plim } A)^{-1}$, where a may be a scalar, vector or matrix,[29] and letting $A = (X^1X)^{-1}X^1Y = \hat{\beta}$, then plim $((X^1X)^{-1}X^1Y)^{-1} = (\text{plim } (X^1X)^{-1}X^1Y)^{-1}$.

Now $(\text{plim } (X^1X)^{-1}X^1Y)^{-1} = \{\beta + \text{plim}(\frac{1}{n} x \overset{1}{-} x)^{-1} \text{ plim}(\frac{1}{n} x\ {}^{1} u)\}^{-1}$

$= (\beta + \Sigma\, xx^{-1}.0 \quad {}^{-1}$ [30]

$= \beta^{-1}$

What is the property of the estimate of log γ ? The consistent estimate of log γ will be $(\hat{\beta}_0/\hat{\beta}_1)$. In addition, using the same procedure that was used to show the consistency of the estimate of $(\delta/1-\delta)$, the estimate of antilog $(\hat{\beta}_0/\hat{\beta}_1)$ will provide a consistent estimate of γ [31]

Using the formula provided in Kmenta[32] for deriving the large sample variance of a restricted coefficient, the variance of γ may be estimated by:

$$\{-\frac{1}{\hat{\beta}_1{}^2}\}^2 \quad . \text{ Variance } (\hat{\beta}_1)$$

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[29] Ibid., pp. 273-274

[30] plim $(\frac{1}{n}X\ {}^1X)^{-1} = \Sigma^{-1}$ XX definitionally.

[31] $\lim\limits_{n\to\infty} E(\text{antilog } (\hat{\beta}_0 / \hat{\beta}_1) \quad \text{antilog } \lim E\ (\hat{\beta}_0/\hat{\beta}_1)$

[32] J. Kmenta, op. cit., p.444

Similarly, the variance of $\hat{Y}$ may be estimated as: $v(\hat{Y})$ = antilog

$$\left\{\frac{1}{\hat{\beta}_1}\right\}^2 \cdot \mathrm{Var}(\hat{\beta}_0) + \left\{\frac{\hat{\beta}_0}{\hat{\beta}_1^{\,2}}\right\}^2 \mathrm{Var}(\hat{\beta}_1) + 2\left\{\frac{1}{\hat{\beta}_1} \cdot \frac{\hat{\beta}_0}{\hat{\beta}_1^{\,2}}\right\} \mathrm{cov.}(\hat{\beta}_0 \hat{\beta}_1).$$

One more precaution must be taken before estimation begins. Goldberger[33] has indicated that in the case of a double log function, in order to obtain an estimation of the variation in the regression accounted for by the equation, the antilogs of the calculated values of, say, log y, should be taken and then their relationships with observed values, say of y, should be the relevant variables for calculating the goodness of fit. Therefore, in the next chapter, Adj $\bar{R}^2$ indicates that the goodness of fit (adjusted for degrees of freedom) measures the antilogs of the log y values calculated against the observed values of y.

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[33] A.S. Goldberger, op. cit., p.217

CHAPTER IV

INTRODUCTION

It must be acknowledged at the outset that the severity of the data limitations will curtail the level of sophistication that can be achieved in examining the constructed model. Relevant parameter estimates, such as the elasticity of substitution ($\hat{\sigma}$) between factors of production, would normally enter the analysis in the form of a testable hypothethis such as the hypothethis that $\hat{\sigma}$ is invariant amongst the relevant vintages of vessels. It is desirable to test for possible differences in such estimates in light of the fact that they may have important policy implications. Even though such types of tests are largely restricted, given the data limitations, all is not lost. The data which would permit such tests is collected for internal use within the government. If the potential usefulness of such an analysis can be made apparent in terms of its policy implications, (for example providing some answers as to (a) what would have happened to employment in the labour market in the Atlantic groundfish industry in recent years if; (i) there had been no capital subsidization; (ii) if there had been a non-discriminatory subsidization program, i.e., a lump sum subsidy not favoring the capital or the labour market, or (iii) if there had been a labour subsidization program instead of a capital subsidization program, and (b) what will happen to the demand for labour in the Atlantic groundfish industry given; (i) the total allowable catch, (ii) trends in technological change, (iii) alternative methods of quota allocation amongst Canadian fishermen, (iv) unionization of the fisheries

labour market, and (v) alternative forms of subsidization discussed above), then the purpose of this thesis will largely be fulfilled.

ASSUMPTIONS

A. Firms are assumed to be price takers in factor and product markets. Although fishermen have traditionally been paid a portion of the value of the catch. It is assumed that over the course of one fishing season free access into the fishery has had a regulatory effect on wages.

A(2) Over the period of one fishing season, output is assumed to be exogenous. Initially, say for the first voyage of the season, entrepreneurs hire the amounts of capital and labour they feel will be optimal to catch an anticipated level of output. Subsequently, say for the second voyage, they may revise their expected level of catch and accordingly hire or release capital and labour so as to minimize costs subject to their revised expectations. However, during the course of the season, it is assumed that sufficient knowledge of biological conditions in the sea is accumulated such that the expected level of catch is actually the realized catch (and hence the two are equivalent), subject to this level of catch, capital and labour are employed to the extent that costs are minimized.

DEFINITION OF TERMS

Unit of Observation -- the fundamental unit of observation employed in this analysis represents the level of output and the amounts of capital and labour employed by a particular vessel over the course of one fishing season. Hence, the unit of observation used here is equivalent to manufacturing studies performed at the plant level. The earliest vintage of vessel selected for study was 1960 as obsolescense and/or physical wear and tear were presumed to have taken their course on prior vintages; unfortunately, the latest vintage available for study was 1968, (appendix III).

Labour (L) -- Labour is defined in terms of manhours. The average number of men employed each year, multiplied by the number of hours spent fishing is defined as being the number of manhours employed.

Wage Rate (W) -- The wage rate represents the total wage bill (which is composed of the net crew share of the value of output, commissions, provisions and other wages) divided by the total number of manhours.

Capital (K) -- If ever there was a nasty problem in economics, defining a unit of capital must be it.[34] Originally, an

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[34] See for example Harcourt and Laing Capital and Growth (1973).

attempt was made to calculate the net value of capital stock, however, the data on hand was insufficient for such a calculation. Surprisingly enough, the more recent observations lacked the detail required to calculate such a value. Furthermore, had such an approach been feasible, it would have introduced the problem of finding a suitable price deflator which could separate out the increase in the value of capital stock, due to an increase in the general price level from the increase due to its increased value in production. Even before this, questions would be raised concerning the correct rate of depreciation. Alternatively then, capital was defined in terms of a physical unit, referred to as a vessel ton hour. While this definition is not without its drawbacks, it does mitigate the problem of finding a suitable deflator. It was felt that a vessel ton hour, which represents the net tonnage capacity of a vessel per hour of fishing, would represent fairly accurately the fundamental unit of working capital in the groundfish industry. Subsequent improvement, say from additional investment, could be explained in the model in the form of disembodied technical change. Furthermore, such a definition enables the comparison of vessels in this study with fishing enterprises of other countries (of course, international differences in the value of currencies would have to be removed). The major drawback is that a vessel ton hour, as a definition of a unit of capital, is not amenable to inter industry studies.

However, for the pruposes set forth in this study, this is not a major point.

The Interest Rate (R) -- The interest rate represents the depreciation on original and subsequent investments, plus operating maintenance and repair expenditures per vessel ton hour.

Quantity of Output -- This represents the tonnage of groundfish caught per year.

Vintage Trend Variable (V) -- This is a trend variable designed to explain observed shifts in certain technical parameters of the production function over various vintages of capital. In the factor proportions equation it reveals whether or not there has been a gradual (disembodied) technical change in capital intensity and in the demand equation it indicates whether there has been any (disembodied) neutral technical change..

ESTIMATION AND HYPOTHESIS TESTING

The Factor Proportions Equation: Estimating the Vessel Expansion Path.

Ideally, one would desire a sample size large enough to permit extensive testing on estimates which have imported policy implications. In the case at hand, for example, the Chow test[35] could be used to test for the equality of these regression coefficients. However, such a type of an analysis was largely restricted due to data limitations.

Nevertheless, the following version was estimated:

$$\log(K/L)i = \hat{\beta}_0 + \hat{\beta}_1 \log(W/R)i + \hat{\beta}_2 V + \hat{u}i, \quad i=1\ldots98$$

There were 98 observations - 8 observations on vessels of the vintage year 1960, 12 observations on vessels of the vintage year 1961, 12 observations on vessels of the vintage year 1962, 22 observations on vessels of the vintage year 1963, 18 observations on vessels of the vintage year 1964, 10 observations on vessels of the vintage year 1965, 11 observations on vessels of the vintage year 1968, 3 observations on vessels of the vintage year 1967 and 2 observations on vessels of the vintage year 1968.

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[35] G.C. Chow "Tests of Equality Between Sets of Coefficients in Two Linear Regressions" Econometrica Vol. 28 July 1960. pp. 591-605

From this, it should be apparent that the Durbin Watson statistic is not appropriate, sample represents a pooling of cross sectional and term series data - sometime referred to as pannel data). In place of the Durbin Watson statistic then the Runs test[36] was employed to test the hypothesis that the residuals exhibited a random pattern.

The following results were indicated:

$$\log(K/L)_i \quad = .81 \quad + .02V \quad + .63 \log(W/R)_i$$

standard error (.14)* (.01)** (.06)***

$\bar{R}^2 = .56$ $\hat{\delta} = .78$

Runs test: $(\hat{UR}: n_1 = 41, n_2 = 57) = 48.7$

From the sample data: $\hat{R} = 47$

At the 95% level of confidence UL= 61.0
LL= 36.3

F statistic = 62.0 $F(1,95\ df \sim .05) \simeq 4.0$

* significantly different from 0 at the 99% confidence level
** significantly different from 0 at the 95% confidence level
*** significantly different from 0 and 1 at the 99% confidence level

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[36] For example, see N.R. Draper and H. Smith Applied Regression Analysis, pp. 95-99, or R. Levin, Statistics for Management, pp. 393-4

According to this particular specification, the adjusted goodness of fit, $(\bar{R}^2)$, was approximately equal to .56, indicating that 56 per cent of the variation in the dependent variable was explained.

Although this is not a particularly good fit, it was the best that could be generated given the data. For instance, if there were more observations available for each vintage year the model could be set up to test for differences in the parameter estimates ($\hat{\sigma}$ and $\hat{\delta}$).

The F statistic provided strong evidence against the hypothesis

$H_0: \beta_0 = \beta_1 = \beta_2 = 0$

(the alternative hypothesis, Ha was $Ha: \beta_0, \beta_1, \beta_2 \neq 0$) at the 5% level of significance.

The Runs test provided no evidence against the hypothesis that the error terms were distributed randomly. No heteroscedasticity appeared to be present when the residual was plotted against log (W/R).

The elasticity of substitution between capital and labour for all vessels, was estimated to be .63, indicating that a one percent change in the relative factor prices generated a .63 percent change in factor proportions. Given the sample data, σ and its distribution, it was possible to reject both the "Leontieff" hypothesis. ($H_0: \hat{\sigma} = 0$ vs Ha $\hat{\sigma} \neq 0$), and the "Cobb Douglas" hypothesis, ($H_0^1\ \hat{\sigma} = {}^1$ vs $H_0\ \hat{\sigma} \neq 1$) at the 99% level of confidence.

The estimated intercept term (.81) combined with the estimated value of σ , yielded an estimate of the capital intensity parameter for the initial vintage of vessel, ($\hat{\delta}$ =.78).

The estimate of the capital intensity parameter was significantly different from 0 at the 99% level confidence.

The vintage trend variable indicated that capital intensity had been increased at the rate of 1.8% for each new vintage of vessel that was introduced. Thus given a particular factor price ratio, a vessel built in year t+1 would exhibit a greater capital intensity than a vessel built in the year t. This estimated trend was significantly different from 0 at the 95% level of confidence.

The Demand for Labour in the Atlantic Groundfish Industry.

One minor problem in production function analysis via econometric techniques is that the parameters are assumed to be the same for the sample data collected. In the context of the demand for labour equation this imposes that one technical efficiency parameter and one return to scale parameter preside over the entire range of vessels. If this is not genuinely true in the context of the estimate of returns to scale, (that is if returns to scale are increasing for small scale firms, constant for intermediate scale firms and decreasing for large scale firms, as is often suggested in economic literature) then a model that depicts a single return to scale

estimate will overestimate the output-employment relationship for small scale vessels and under-estimate the output employment relationship for large scale vessels.

In this study, a preliminary model was run depicting only one estimate of technical efficiency and one estimate of returns to scale for the entire range of vessels. Upon examination of the residuals, a heteroscedaster error term combined with a non randomly distributed error term (according to the Runs test) led to the following version:

$$\log Li - \hat{\hat{\sigma}}/1 - \hat{\hat{\sigma}} \log \hat{\hat{Z}} = -1/\nu_0 \log \gamma_0 - 1/\nu_1 \log \nu_2 - 1/\gamma_2 \log$$

$$+1/\nu_0 \log Q_0 + 1/\nu_1 \log Q_1 + 1/\nu_2 \log Q_2 + \Sigma i, \quad i=1...98$$

This version may be written alternatively as:

$$\log Li - \hat{\hat{\sigma}}/1 - \hat{\hat{\sigma}} \log Zi = \hat{\partial}_0 + \hat{\partial}_1 + \hat{\partial}_2 + \hat{\partial}_3 \log Q_0 + \hat{\partial}_4 \log Q_1$$

$$+ \hat{\partial}_5 \log Q_2 + \Sigma i, \quad i=1...98$$

In this specification, the sample was divided such that $\hat{\partial}_0$ and $\hat{\partial}_3$ provided estimates of technical efficiency and returns to scale, respectively, for vessels with $<$ 50 net tons capacity, $\hat{\partial}_1$ and $\hat{\partial}_4$ provided estimates of technical efficiency and returns to scale, respectively, for vessels with $>$ 50 net tons capacity and $<$ 100 net tons capacity and $\hat{\partial}_2$ and $\hat{\partial}_5$ provided estimates of technical efficiency and returns to scale, respectively, for vessels with $>$ 100 net tons capacity.

Furthermore, $\hat{\sigma}/1-\hat{\sigma}$ was obtained from estimates of $\hat{\sigma}$ in the factor proportions equation and log $\hat{z}i$ was generated from estimates $\hat{\sigma}$ and $\hat{\delta}$ in the factor proportion equation and observations on (W/R) as follows:

$$\log \hat{z}i = \{\hat{\delta}e^{\hat{\beta}_1 V}\left(\frac{1-\hat{\delta}e^{\hat{\beta}_1 V}}{\hat{\delta}e\hat{\beta}_1 V}\right)^{1-\hat{\sigma}}\left(\frac{R}{W}\right)^{1-\hat{\delta}}+1-\hat{\delta}e^{\hat{\beta}_1 V}\} \qquad (37)$$

The results were as follows:

letting $\log Li-\hat{\sigma}/1-\hat{\sigma} \log zi = \log NLi$,

$\log \hat{NL}i = 4.49C_2 + 8.48C_2 + 7.81C_3 + .66 \log Q_1i + .20 \log Q_2i +$

standard error:

(1.13)* (.46)* (1.67)* (.18)* (.06)*

$.39 \log Q_3i + \varepsilon i, \hat{\nu}_0 = 1.5, \hat{\nu}_1 = 5.1, \hat{\nu}_2 = 2.5$

(.22)** (.17)* (2.7)** (2.0)***

and $\hat{\gamma}_2 = .01^+$, $\hat{\gamma}_1 = .00^+$ and $\hat{\gamma}_2 = .00^+$

(2.16) (13.70) (9.75) $\bar{R}^2 = .77$

Runs test $n_1 = 57$ $(\hat{U}Rn_1 = 57, n_2 = 41) = 48.7$

At the 5% level of significance

$\hat{R} = 45$ UL = 58.1

LL = 39.3

F statistic ≃ 52.0 F(5,92 df, 5%) ≃ 2.3

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[37] M. Brown. op. cit. (pg 139) Note that: e = 2.71828

* significantly different from 0 at the 99% level of confidence
** significantly different from 0 at the 90% level of confidence
***significantly different from 0 at the 80% level of confidence
+ not significantly different from 0 at the 80% level of confidence.

The adjusted goodness of fit for this specification was equal to .77 indicating that 77% of the variation in the dependant variable was explained.

The F statistic provided strong evidence against the hypothesis H_0: $\hat{\partial}_0=\hat{\partial}_1=\hat{\partial}_2=\hat{\partial}_3=\hat{\partial}_4=\hat{\partial}_5= 0$
as opposed to Ha: $\hat{\partial}_0, \hat{\partial}_1, \hat{\partial}_2, \hat{\partial}_3, \hat{\partial}_4, \hat{\partial}_5 \neq 0$
at the 5% level of significance.

The runs test provided no evidence against the hypothesis that the error terms were randomly distributed.

The estimates of returns to scale provided some interesting, even provocative results. For each of the three groupings of vessels, ($<$50 net tons, 50-100 net tons and $>$100 net tons), increasing returns to scale were indicated. More particularly for small scale vessels the estimate of returns to scale was significantly greater than 1 at the 99% level of confidence; for intermediate scale vessels the estimate of return to scale was greater than it was for small scale vessels however, the estimate was less precise and was significantly greater than one only at the 90% level of confidence and, for large scale vessels the estimate of returns to scale, while

less than that for intermediate scale vessels, was still greater than it was for small scale vessels however, the estimate was the least precise of all and provided no evidence against the hypothesis that the return to scale was greater than 0 (as opposed to $Ha\ \hat{\nu}_2 \neq 0$) at the 90% level of confidence. Perhaps this drop in precision would suggest that the sample should be further subdivided - possibly into 5 or 6 groupings of vessels on the basis of scale. If more observations were made available this possibility could be investigated.

One problem encountered with the results is that the cost minimization framework is generally established in the presence of purely competitive firms and pure competition is not compatible with increasing returns to scale. However, the following explanations are offered as to the results:

(1) that the sample, were it larger, would enable one to further subdivide the vessels on the basis of scale and would lead to estimates of constant returns to scale for large scale vessels, (which individually produce only a small fraction of the industry output)

(2) returns to scale at the firm level may provide lower estimates than those which were performed at the vessel level in this study.

Unfortunately no concrete statement could be made about the technical efficiency employed by the various groupings of vessels.

CHAPTER V

SUMMARY

Although data limitations were severe, the econometric study did produce some interesting and potentially important results, namely:

(1) Employment in the Atlantic provinces will be effected not only by the prescribed level of industry output (quota) but also by how that total is distributed according to the vintage of vessel and the scale of vessel, because

(2) Capital intensity was estimated to be increasing at a rate of 1.8% with each new vintage of vessel, and

(3) Returns to scale were estimated to be 1.5 for small scale vessels, 5.1 for intermediate scale vessels, and 2.5 for large scale vessels.

(4) Furthermore, the elasticity of substitution between capital and labour for all vessels was estimated to be .63, significantly greater than 0 and less than 1 at the 99% level of confidence, and

(5) No precise estimate could be obtained for the technical efficiency parameter.

POLICY IMPLICATIONS

Two major policy variables are presently employed in the Atlantic groundfish industry - the quota and the input subsidy. The quota's main function is as a regulatory device on the quantity of output that can (legally) be produced, whereas the input subsidy can

be used to effect the optimal combination of factors of production for a particular level of output.

The economic construct that has been developed in this thesis can be utilized, to a certain extent, to determine the implications of alternative forms of quota allocation or input subsidies on economic activity. However, the possible tradeoffs which may be achieved will be discussed conceptually as opposed to quantitatively since, given the crudeness of the data, quantitative estimates would have little meaning and would require numerous detailed calculations.

In discussing quota allocation the logical framework for analysis may be viewed as objectives, criteria and method - in sequential order. Presumably, the objective of the government is to maximize the social welfare of its citizens. However, to do so it must have certain criteria upon which it can decide what is "optimal". What is optimal in terms of the market (economic) part of the economy generally depends upon the following criteria: economic efficiency, equity, stability, full employment and growth.

Certain limitations of this model are apparent. First, it is an economic model and as such can only examine economic issues (as opposed to social or political issues) and only certain economic issues at that. For example, this model has nothing to say about economic stability - it takes output as an exogenous variable. Nevertheless, given the economic criteria which it can evaluate, the

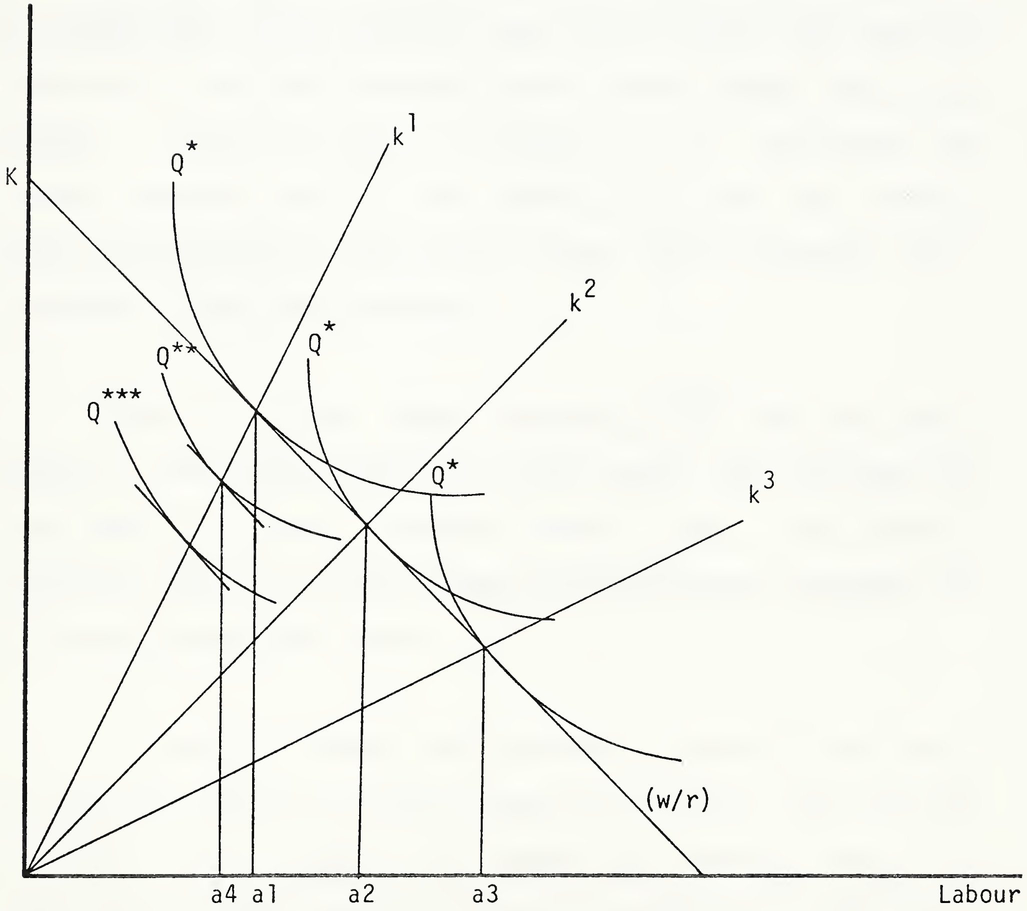
final step is selecting the method of quota allocation (for example, transferable vs. non transferable) which is consistent with the policy objectives and criteria.

If the expansion path of vessels in the atlantic groundfish industry is defined in terms of cost minimizing combination of capital and labour for particular levels of output, given the capital labour price ratios, then it may be said that for a given level of industry output, the actual expansion path for the industry depands upon what portion of total output is allocated to various vintages of vessels. In other words, given the apparent increase in capital intensity with the introduction of new vintages of vessels, a number of industry expansion paths could be generated, each depending upon how much of the industry output was allocated to each vintage. For instance, in figure x, given relative factor prices (W/R), if a large percent of industry output were allocated to more recent vintages of capital the industry expansion path might be represented by k^1 ; alternatively, if a large percent of industry quota were allocated to older vintages of vessels, the industry expansion path could be represented by k^3. If industry output were represented as Q^* in figure x, all three expansion paths (k^1,k^2,k^3) could yield the same level of economic efficiency in factor markets, with expansion path k^3 being more labour intensive.

In this instance, an allocation to vessels representing expansion path k^3 may be deemed desirable since it sacrifices no

FIGURE X

Alternative Industry Expansion Paths Determined by Allocating Quota to Different Vintages of Capital



economic efficiency and utilizes more labour.

However, recall from chapter IV that returns to scale varied according to the scale of vessel. Given this information it may be seen that if the industry quota were allocated to small vessels (<50 net tons) then a given level of quota would require more resources than would a plan that allocated industry output amongst large scale vessels. (≥ 100 net tons). In figure x, if represented the industry expansion path of the adopted quota plan then industry output Q^{**}(allocated to large scale vessels) may be equivalent to Q^{*} (allocated to small scale vessels).

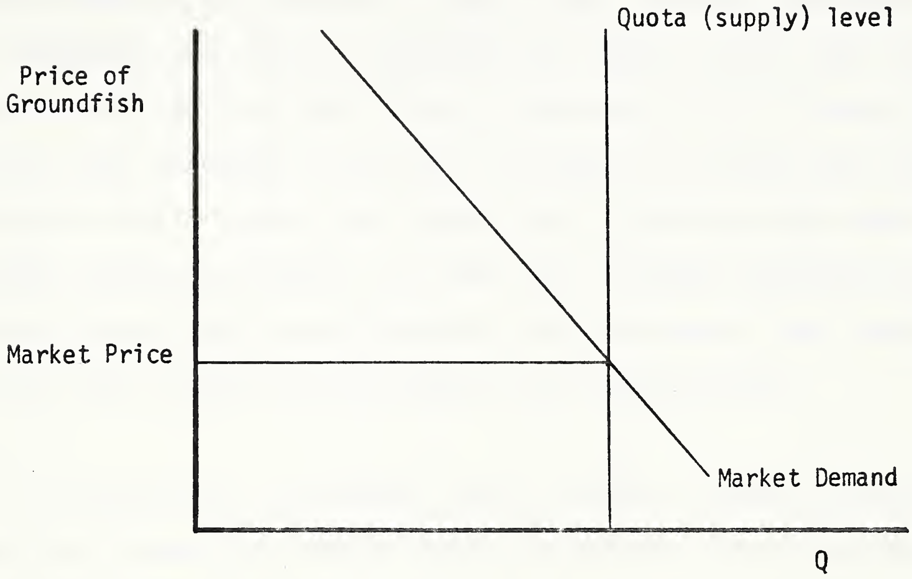
Clearly the first scheme (allocating Q^{**} to the large scale vessel) is economically efficient to the scheme that allocates the same amount of output to smaller vessels. Thus in the Atlantic groundfish industry a trade off must be made between employment and allocative economic efficiency.

In regards to equity, under perfectly competitive conditions, the equitable allocation of quota amongst participating firms would be determined by the market (for example as determined through a transfereable scheme) since all factors of production are paid their value in production. Even in pure competition the market would determine an equitable quota allocation. However, this presumes that product prices would remain exogenous - being determined by supply and demand such as in figure XI (a). As an alternative, if the quota were

FIGURE XI

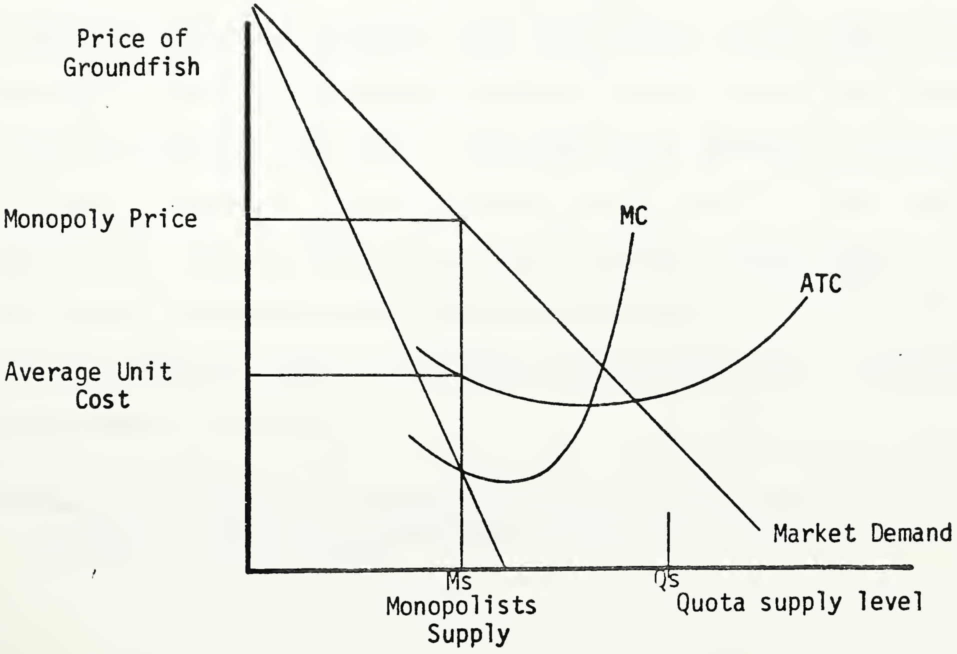
Pricing Under a Purely Competitive Structure

(a)



(b)

Pricing Under a Pure Monopoly



made transferable, and there were increasing returns to scale at the firm level (a question requiring empirical examination) then prices could become endogenous and in the limit approach a monopoly like situation such as that depicted in figure XI(b). In such a situation, the monopolist may find it profitable to supply say MS even if industry quota were set at QS. If QS is equivalent to Q** in figure x then MS might correspond to say Q*** in figure x in which case (1) employment would be reduced even further than it would have been under a purely competitive industry, (2) the loss in pricing efficiency in product markets could be sufficient to offset any gains which might have been made in allocative efficiency in the factor markets.

To demonstrate the possible shift in market structure pricing conduct and economic performance given a transferable quota scheme and increasing returns to scale, consider figure XII which depicts two representative enterprises; the small scale enterprise having average total cost ATCM and marginal cost MCM and the large scale (say vertically integrated) enterprise having an initial average total cost ATCVE and marginal cost MCV.[38] Now suppose the government allocates a certain amount of quota to each, say Q_m to the small scale enterprise and Q_V to the large scale enterprise (figure XII). If the current (exogenous) market price is represented as MP (figure XII) then the value or cost of the quota to the large scale enterprise would appear to be $MP.Q_m$

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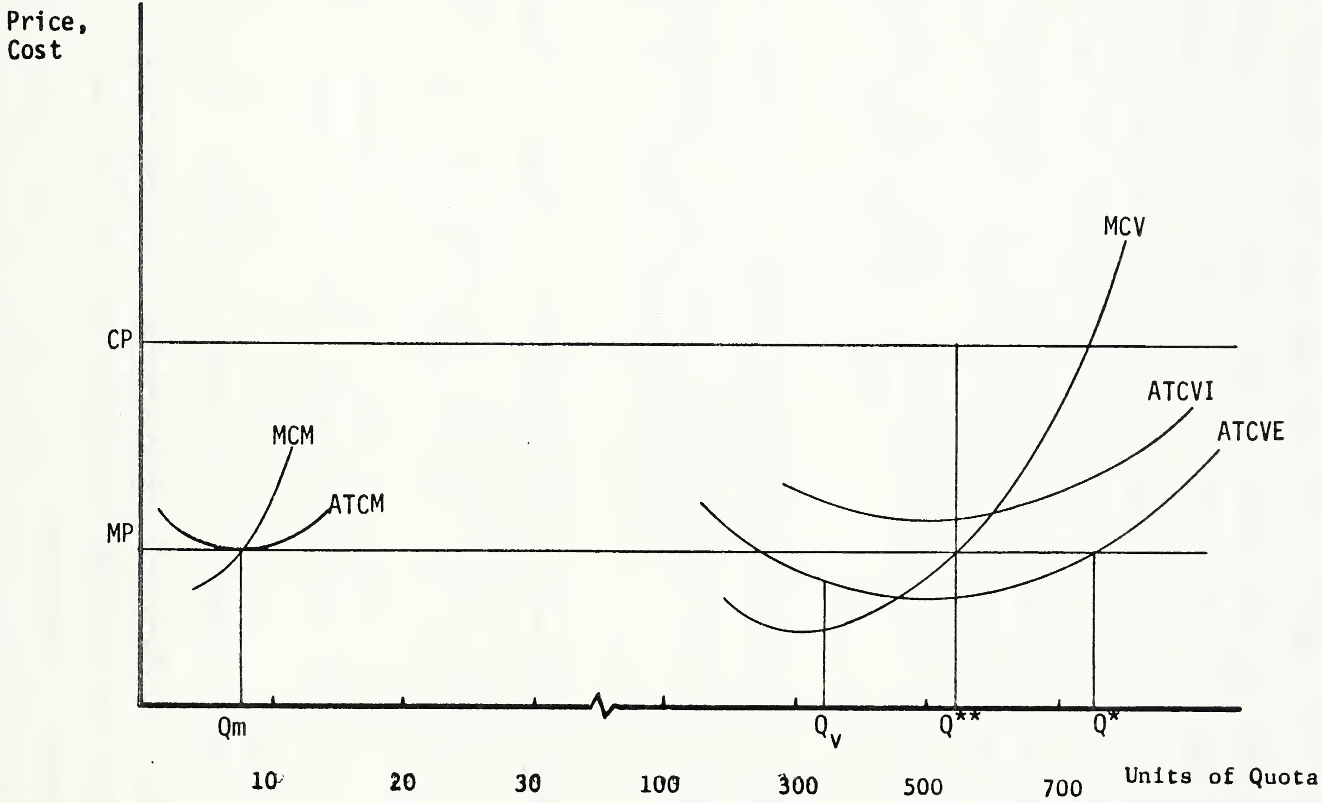
[38] Returns to scale and economies of scale are not the same phenomenon however the co-existence of the two are highly probable as will be shown.

FIGURE XII

Transferable Rights and the Possible Effects on Pricing Efficiency in the Atlantic Groundfish Industry



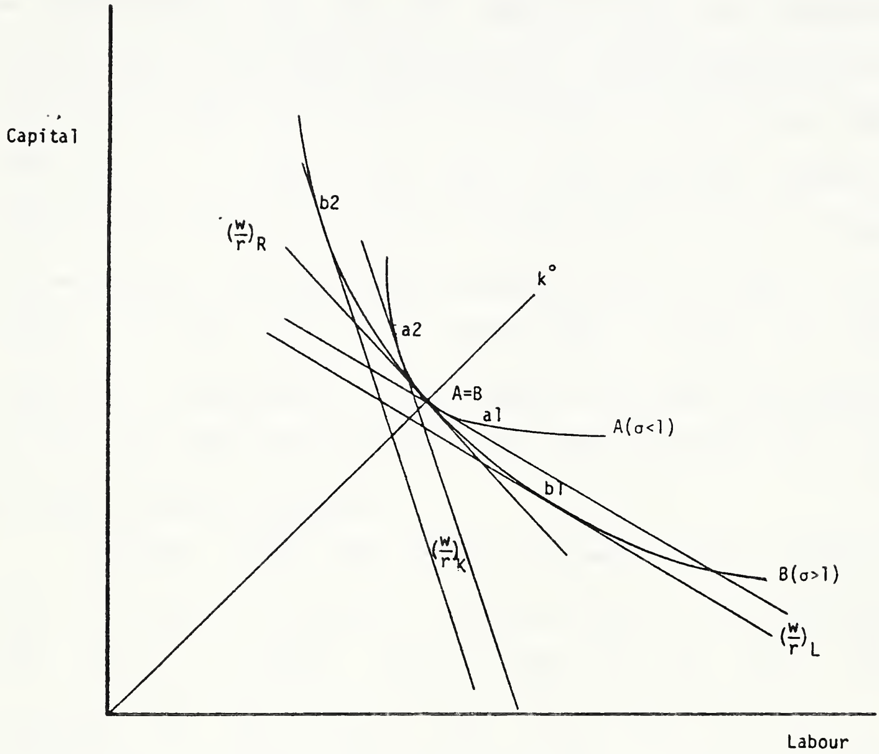
However, if the large scale enterprise can make a sufficient number of purchases from small scale operators (say Q*-Qv in figure xii), such that it achieves the necessary amount of market power to determine product prices internally then the real ultimate value of the quota to the large scale enterprise would be much greater than MP.Qm, perhaps CP.Qm in figure XII, where CP would be the price level set by the large scale enterprise. If the large scale operations average total cost increased with the acquisition of quota to ACTVI and it has the right to catch Q* it may be to the advantage of the large scale operation to restrict output to say Q**.

The acquisition of quota by the large scale enterprise may be extremely profitable for the large scale enterprise should it acquire the market power to obtain control over prices.

However, in regards to the equity issue and the possibility of transferable vs. non transferable rights the above discussion has proceeded on the tentative findings of the study along with some theoretical introspection into market structure conduct and performance. Before any truly concrete statements can be made concerning best method of quota allocation, (completely institutionalized, completely transferable or somewhere along the spectrum) further research is required which will analyse (1) returns to scale at the firm level (2) economies of scale in the Atlantic groundfish industry and (3) call upon concentration literature pertaining to the groundfish industry for an intertemporal overview of the structure and performance of the industry.

FIGURE XIII

The Costs of Alternative Subsidization Programs and Their Affect on the Economically Efficient Combination of Capital and Labour



In regards to the likely effects and costs of various subsidization programs this model provided some interesting results. The elasticity of substitution between capital and labour was found to be significantly less than one implying that (a) entrepreneurial decision on the efficient combination of capital-labour will be less sensitive to given alterations in the relative factor prices than they would be if (σ) were larger, and (b) an artificial change in the factor price ratio will require a greater total cost on the part of the entrepreneur (keeping output constant) then it would if (σ) were larger. In other words, for a given level of output, the less the elasticity of substitution between capital and labour the greater will be the social cost of maintaining that level of output when a capital or labour subsidy is applied.

Consider Figure XIII given the real (market) factor price ratio $(\frac{W}{r})R$ and two production functions A and B (both producing the same level of output), characterized only by their differing elasticity of substitution, such that σ of A $<\sigma$ of B. The economically efficient position for both A and B is along k^0, exactly where depending upon the level of output. Now what happens if labour is subsidized and output, say the total allowable catch, is held constant; that is, if the factor price ratio is now $(\frac{W}{r})L$. The optimal factor proportions for A will be a_1 and the optimal factor proportions for B will be at b_1 and it is clearly evident that the iso cost of A $>$ B (Figure XIII). In other words, given this alteration in relative (market) factor prices, firm A is less efficient relative to B, and its optimal factor

TABLE V

Idle Vessel Capacity in the Atlantic Groundfish Industry[1]

Year	Total (Potential) Net Tonnage	Total (Actual) Net Tonnage	% Utilization
1976	417.3	150.9	36.1
1975	590.8	210.6	35.6
1974	547.1	210.0	38.3
1973	537.7	263.1	48.9
1972	433.9	143.9	33.1
1971	639.7	237.4	37.1
1970	907.7	456.0	50.2
1969	929.5	507.0	54.5
1968	1,282.3	665.9	51.9
1967	1,730.3	943.9	54.5
1966	1,230.7	713.2	57.9
1965	254.3	188.4	74.0
1964	229.2	148.1	64.6
1963	142.0	55.3	38.9
Average 1963-1976			48.3

[1] On a per trip basis

Source: J.P. Charron and J. Proskie, "Costs and Earnings of Selected Fishing Enterprises", Department of Fisheries, Ottawa. Publications, 1963-1976.

proportions have been effected more. Similarly, this situation is depicted in Figure XIII for a capital subsidy program. Given the capital subsidized factor price ratio $(\frac{w}{r})K$ for the given level of output, A will find it optimal to employ factor proportions at a_2 and B will similarly find it optimal to move to b_2 with the total cost of firm A is greater than that of firm B, $A > B$. Alternatively, a non-discriminatory subsidy program would not alter the optimal factor proportions employed by either A or B and would thus not render production technique A inefficient to B.

In the Atlantic groundfish industry input subsidization along with certain findings of the study have overt economic significance. First, the input subsidization program has tended to replace labour with capital. Second, there has been a natural substitution of capital for labour with the introduction of newer vessels. Finally, the low degree of substitutability between capital and labour results in a higher social cost if a given level of output is to be maintained after a capital subsidy has been applied; than it would if (σ) were larger.

In addition in connections with capital subsidies, there may be the problems of asset fixity and excess capacity. According to sample data between 1963 and 1976 the percent of net tonnage capacity that was actually utilized per trip averaged 48.32 ranging from 74% in 1965 to 33.1% in 1972 (table V).

The extent to which various subsidization programs induce or

enhance excess capacity and/or asset fixity has not been examined here and perhaps this area should be investigated.

Philosophical Issues and Methodological Problems

Presumably, one of the primary objective of government is to maximize the social welfare of its citizens. Exactly what this entails however, has been somewhat elusive to both the politician and economist alike. At any rate, it appears to include some complex set of objectives such as economic efficiency, equity, full employment, economic stability and growth, in which some tradeoffs as has been shown are inevitable. Which tradeoff is socially optimal? The branch of economics which purports to deal with such issues is economic policy and as might be expected, this branch occupies a singularly normative position in economic analysis. Economic models, such as the one generated in this thesis, are generally the constructs developed to guide policy in achieving the best tradeoff. Economic models, in general, inherently address the economic costs and benefits associated with various tradeoffs and lack social impetus. What is the social value (cost) of full employment (a high degree of unemployment)? Perhaps including some social aspects of welfare to the material aspects measured in economic models, would completely alter the socially desireable tradeoffs. In addition to this type of problem there are the perennial problems of measurement (for example measuring

capital, differences in entrepreneural ability, etc.) and having a sufficiently realistic construct to explain and predict economic behaviour.[39]

Limitations and Unanswered Questions

The major limitations of the model may be summarized as follows:

(1) it incorporates only economic variables, lacking any social and political input

(2) it fails to explain why total output is set at various levels that is it does not incorporate economic stability, and

(3) due to data limitations the analysis was undertaken at the vessel level whereas a more informative and relevant analysis could be undertaken at the firm level.

Unanswered questions may be directed toward the following:

(1) How do returns to scale behave at the firm level?

(2) How do economies of scale behave at the firm level?

(3) What is the state of concentration in the Atlantic groundfish industry and how has it changed over the past decade? and,

(4) How do input subsidies and/or asset fixities effect idle capacity in the Atlantic groundfish industry?

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[39] see for example P. Yotopoulos and J. Negent Economics of Development : Empirical Investigations 1976 and Harcourt and Laing : Capital and Growth, 1973

CONCLUDING REMARKS

This thesis has attempted to elucidate both the usefulness and limitations associated with using an economic model to guide policy in the Atlantic groundfish industry. As with most models it can be utilized to evaluate the economic benefits and costs associated with various tradeoffs. However, it does lack social and political impetus.

Severe data limitations were encountered in the study which restricted the usefulness of the anlaysis. However, it is recommended that given sufficient data, a more sophisticated (realistic) model could be constructed which would be very useful for policy purposes.

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APPENDIX I

LIST OF NORTHWEST ATLANTIC SPECIES ARRANGED ACCORDING TO THE ICNAF GROUPS

Common English Name	Scientific Name
PRINCIPAL GROUNDFISH (EXCEPT FLATFISHES)	
Atlantic cod	Gadus morhua
Haddock	Melanogrammus aeglefinus
Atlantic redfish	Sebastes sp.
Silver hake	Merluccius bilinearis
Red hake	Urophycis chuss
Pollock (=Saithe)	Pollachius virens
FLATFISHES	
American plaice	Hippoglossoides platessoides
Witch flounder	Glyptocephalus cynoglossus
Yellowtail flounder	Limanda ferruginea
Greenland halibut	Reinhardtius hippoglossoides
Atlantic halibut	Hippoglossus hippoglossus
Winter flounder	Pseudopleuronectes americanus
Summer flounder	Paralichthys dentatus
Windowpane flounder	Scophthalmus Aquosus
Flatfishes (NS)	Pleuronectiformes
OTHER GROUNDFISH	
American angler (=Goosefish)	Lophius americanus
Atlantic searobins	Prionotus sp.
Atlantic tomcod	Microgadus tomcod
Cunner	Tautogolabrus adspersus
Cusk (=Tusk)	Brosme brosme
Greenland cod	Gadus ogac
Ling	Molva molva
Lumpfish (=Lumpsucker)	Cyclopterus lumpus
Northern kingfish	Menticirrhus saxatilis
Northern puffer	Sphoeroides maculatus
Ocean pout	Macrozoarces americanus
Polar cod	Boreogadus saida
Roundnose grenadier	Macrourus rupertris
Sandeels (=Sand lances)	Ammodytes sp.
Sculpins	Myoxocephalus sp.
Scup	Stenotomus chrysops
Tilefish	Tautoga onitis
White hake	Lopholatilus chamaeleonticeps
Wolffishes (=Catfishes)	Urophycis tenuis
Groundfish (NS)	Anarhichas sp.

Common English Name	Scientific Name
PRINCIPAL PELAGICS	
Atlantic herring	Clupea harengus
Atlantic mackerel	Scomber scombrus
OTHER PELAGIC FISH	
Atlantic butterfish	Peprilus triacanthus
Atlantic menhaden	Brevoortai tyrannus
Atlantic saury	Scomberesiz saurus
Bay anchovy	Anchoa mitchilli
Bluefish	Pomatomus saltatrix
Crevalle jack	Caranx hippos
Frigate mackerel	Auxis thazard
King mackerel	Scomberomorus cavalla
Spotted Spanish mackerel	Scomberomorus maculatus
Atlantic sailfish	Istiophorus platypterus
Atlantic white marlin	Tetrapturus albidus
Blue marlin	Makaira nigricans
Swordfish	Xiphias gladius
Albacore	Thunnus alalunga
Atlantic bonito	Sarda sarda
Atlantic little tunny	Euthynnus alletteratus
Bigeve tuna	Thunnus obesus
Bluefin tuna	Thunnus thynnus
Skipjack tuna	Katsuwonus pelamis
Yellowfin tuna	Thunnus albacares
Tunas (NS)	Scombridge (=Thunnidae)
Pelagic fish (NS)	...
OTHER FISH	
Alewife	Alosa pseudoharengus
Amberjacks	Seriola sp.
American conger	Conger oceanicus
American eel	Anguilla rostrata
American shad	Alosa sapidissima
Atlantic argentine	Argentina silus
Atlantic croaker	Micropogon undulatus
Atlantic needlefish	Strongylura marina
Atlantic salmon	Salmo salar
Atlantic silverside	Menidia menidia
Atlantic thread herring	Opisthonema oglinum
Black drum	Pogonias cromis
Black seabass	Centropristis striata
Blueback herring	Alosa aestivalis
Capelin	Mallotus villosus
Chars (NS)	Salvelinus sp.
Cobia	Rachycentron canadum
Common pompano	Trachinotus carolinus
Gizzard shad	Dorosoma cepedianum
Grunts (=Grunters)	Pomadasyidae

Common English Name	Scientific Name
OTHER FISH (continued)	
Hickory shad	Alosa mediocris
Mullets	Mugilidae
North Atlantic harvestfish	Peprilus alepidotus
Pigfish	Orthopristis chrysoptera
Rainbow smelt	osmerus mordax
Red drum	Sciaenops ocellata
Red porgy	Pagrus sedecim
Rough scad	Trachurus lathami
Sand perch	Diplectrum formosum
Sheepshead	Archosargus probatocephalus
Spot	Leiostomus xanthurus
Spotted weakfish	Cynoscion nebulosus
Squeteague	Cynoscion regalis
Striped bass	Morone saxatilis
Sturgeons	Acipenseridae
Tarpon	Megalops atlantica
Trouts (NS)	Salmo sp.
White perch	Morone americana
Spiny (=picked) dogfish	Squalus acanthias
Dogfishes (NS)	Squalidae
Porbeagle	Lamma nasus
Sharks (NS)	Squaliformes
Skates (NS)	Raja sp.
Finfishes (NS)	...
INVERTEBRATES (Molluscsand Crustaceans)	
Long-finned squid (Loligo)	Loligo pealei
Short-finned squid (illex)	Illex illecebrosus
Squids (NS)	Lolifinidaw, ommastrephidae
Atlantic razor clam	Ensis directus
Hard clam	Mercenaria mercenaria
Ocean quahog	Arctica islandica
Soft clam	Mya arenaria
Surf clam	Spisula solidissima
Clams (NS)	...
Bay scallop	Argopecten irradians
Calico scallop	Argopecten gibbus
Sea scallop	Placopecten magellanicus
Scallops (NS)	Pectinidae
American cupped oyster	Crassostrea virginica
Blue mussel	Mytilus edulis
Conchs	Strombus and Busycon sp.
Periwinkles	Littorina sp.
Marine Molluscs (NS)	...
Atlantic rock crab	Cancer irroratus
Blue crab	Callinectes sapidus
Green crab	Carcinus maenas
Jonah crab	Cancer borealis

Common English Name	Scientific Name
INVERTEBRATES (Continued)	
Queen crab	Chionoecetes opilio
Red crab	Geryon Quinquedens
Marine crabs (NS)	...
Northern lobster	Homarus americanus
Northern deepwater prawn	Pandalus borealis
Pink shrimps (=Prawns)	Panalus sp.
Marine crustaceans (NS)	...
American sea-urchin	Strongylocentrotus sp.
Marine worms (NS)	Polychaeta
Horseshow crab	Limlus ployphermus
Marine invertebrates (NS)	...

Source: International Commission for the Northwest Atlantic Fisheries, Statistical Bulletin, Volume 26, 1977.

APPENDIX II

Deriving the Demand for Labour From the C.E.S. Production Function

(1) $$Q = \gamma(\delta K^{-\rho} + (1-\delta)L^{-\rho})^{-\nu/\rho}$$

(2) $$(\frac{Q}{\gamma})^{-\rho/\nu} = \delta K^{-\rho} + (1-\delta)L^{-\rho}$$

(3) From cost minimization $K/L = (\delta/1-\delta)^{\sigma}(\frac{w}{r})^{\sigma}$

so $K = L(\delta/1-\delta)^{\sigma}(\frac{w}{r})^{\sigma}$

(4) $$(\frac{Q}{\gamma})^{-\rho/\nu} = \delta(L(\delta/1-\delta)^{\sigma}(\frac{w}{r})^{\sigma})^{-\rho} + (1-\delta)L^{-\rho}$$

(5) $$(\frac{Q}{\gamma})^{-\rho/\nu} = \frac{\delta}{L^{\rho}(\delta/1-\delta)^{\sigma\rho}(\frac{w}{r})^{\sigma\rho}} + \frac{1-\delta}{L^{\rho}}$$

(6) $$(\frac{Q}{\gamma})^{-\rho/\nu} = \frac{\delta + (1-\delta)(\delta/1-\delta)^{\sigma\rho}(\frac{w}{r})^{\sigma\rho}}{L^{\rho}(\delta/1-\delta)^{\sigma\rho}(\frac{w}{r})^{\sigma\rho}}$$

(7) $$\frac{L^{\rho}}{(\frac{Q}{\gamma})^{\rho/\nu}} = \frac{\delta + (1-\delta)(\delta/1-\delta)^{\sigma\rho}(\frac{w}{r})^{\sigma\rho}}{(\delta/1-\delta)^{\sigma\rho}(\frac{w}{r})^{\sigma\rho}}$$

and since $1/\rho = (\sigma/1-\sigma)$ and $\sigma\rho = 1-\sigma$

(8) $$L = (\frac{Q}{\gamma})^{1/\nu}(\frac{\delta}{(\delta/1-\delta)^{1-\sigma}(\frac{w}{r})^{1-\sigma}} + (1-\delta))^{\sigma/1-\sigma}$$

(9) $$L = (Q/\gamma)^{1/\nu}(\delta(1-\delta/\delta)^{1-\sigma}(\frac{r}{w})^{1-\sigma} + (1-\delta))^{\sigma/1-\sigma}$$

(10) $$L = Q^{1/\nu}\gamma^{-1/\nu}(\delta(1-\delta/\delta)^{1-\sigma}(\frac{r}{w})^{1-\sigma} + 1-\delta)^{\sigma/1-\sigma}$$

Furthermore, keeping inside the brackets ( )

$$(11) \quad \left(\delta (1-\delta / \delta)^{1-\sigma} \left(\frac{r}{w}\right)^{1-\sigma} + 1 - \delta \right)^{\sigma/1-\sigma}$$

$$= \left(\delta(1-\delta)^{1-\sigma} \delta^{\sigma -1} r^{1-\sigma} w^{\sigma-1} + 1-\delta \right)^{\sigma/1-\sigma}$$

$$= \left(\delta(1-\delta)^{1-\sigma} \frac{\delta^{\sigma}}{\delta} r^{1-\sigma} \frac{1}{w}^{1-\sigma} + 1-\delta \right)^{\sigma/1-\sigma}$$

$$= \left(\frac{(1-\delta)\ \delta^{\sigma}\ r^{1-\sigma}}{(1-\delta)^{\sigma}\ w^{1-\sigma}} + 1-\delta \right)^{\sigma/1-\sigma}$$

$$= \left(\frac{(1-\delta)\ \delta^{\sigma} r^{1-\sigma} + (1-\delta)\ (1-\delta)^{\sigma}\ w^{1-\sigma}}{(1-\delta)^{\sigma}\ w^{1-\sigma}} \right)^{\sigma/1-\sigma}$$

$$= \left(\frac{\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma}\ w^{1-\sigma}}{(1-\delta)^{\sigma-1}\ w^{1-\sigma}} \right)^{\sigma/1-\sigma}$$

$$= \left((1-\delta)^{1-\sigma} w^{\sigma-1} \right)^{\sigma/1-\sigma} . \left(\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma}\ w^{1-\sigma} \right)^{\sigma/1-\sigma}$$

$$= (1-\delta)^{\sigma}\ w^{\frac{\sigma^{2} - \sigma}{1-\sigma}} \quad . \left(\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma} \right)^{\sigma/1-\sigma}$$

$$= (1-\delta)^{\sigma}\ w^{\frac{-\sigma(1-\sigma)}{(1-\sigma)}} \quad . \left(\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma} \right)^{\sigma/1-\sigma}$$

$$= (1-\delta)^{\sigma}\ w^{-\sigma} \quad . \left(\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma}\ w^{1-\sigma} \right)^{\sigma/1-\sigma}$$

Therefore:

$$(12) \quad \text{Log } L = -1/\nu \log \gamma + 1/\nu \log Q - \sigma \log w + \sigma \log (1-\delta) + \sigma/1-\sigma \log \left(\delta^{\sigma} r^{1-\sigma} + (1-\delta)^{\sigma} w^{1-\sigma} \right)^{*}$$

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* Wallis op. cit. Arrives at the same conclusion (p.55)

APPENDIX III

SURVEY DATA

Province	Year	Vintage	Potential Net Tonnage	Actual Net Tonnage	Percent Utilization	Hours Fished	Man Hours (L)	Vessel ton hours (K)	(K/L)	Wage Rate (W)	Interest rate (r)	(W/r)	Quantity
NS	76	66	277.3	81.3	29.3	2942	44424.2	815816.6	18.364	6.004	.393	15.277	2145.19
NS	76	65	35.3	13.3	37.7	1596	4947.6	56338.8	11.387	9.515	.725	13.124	485.83
NS	76	64	104.7	56.3	53.8	2756	35001.2	288553.2	8.244	4.360	.577	7.556	1387.51
NS	75	66	280.6	90.3	32.2	2784	41760.0	781190.4	18.706	5.725	.366	15.642	2242.87
NS	75	65	35.3	10.2	28.9	1436	4595.2	50690.8	11.031	9.553	.565	16.907	408.96
NS	75	64	103.1	56.4	54.7	2260	28024.0	233006.0	8.314	4.986	.628	7.939	1409.35
NS	75	64	171.8	53.7	44.1	2761	37549.6	336289.8	8.955	4.311	.494	8.726	1396.88
NS	74	66	280.6	86.1	30.7	2647	36528.6	742748.0	20.333	4.559	.302	15.096	2454.92
NS	74	65	35.3	10.3	29.2	1186	3913.8	41865.8	10.696	8.682	.653	13.295	597.39
NS	74	64	103.1	60.6	58.8	2208	27600.0	227644.8	8.248	4.069	.583	6.979	1423.19
NS	74	64	128.1	53.0	41.4	2454	31902.0	298897.2	9.369	3.352	.447	7.498	1290.47
NS	73	66	280.6	123.3	43.9	2930	41899.0	822158.0	19.622	4.759	.211	22.554	3391.55
NS	73	65	35.3	17.5	49.6	1270	4191.0	44831.0	10.696	8.605	.505	17.039	657.65
NS	73	64	121.8	59.3	48.7	3266	47357.0	397798.8	8.400	2.858	.254	11.251	1620.65
NS	73	63	100.0	63.0	63.0	2589	33657.0	258900.0	7.692	3.684	.417	8.834	1653.62
NS	72	66	276.8	78.2	28.3	3230	49419.0	894064.0	18.091	2.762	.183	15.092	2241.50
NS	72	65	35.3	13.1	37.1	1375	4675.0	48537.5	10.382	6.189	.363	17.049	434.43
NS	72	64	121.8	52.6	43.2	3217	45038.0	391830.6	8.700	2.235	.292	7.650	1454.57
NS	71	66	276.8	74.9	27.1	3739	58328.4	1034955.2	17.743	2.161	.143	15.110	2197.93
NS	71	64	99.6	45.5	45.7	2040	17748.0	203184.0	11.448	2.582	.324	7.969	939.90
NS	71	64	100.0	59.8	59.8	2629	35491.5	262900.0	7.407	2.645	.376	7.034	1765.21
NS	71	64	121.8	45.9	37.7	3621	50331.9	441037.8	8.762	1.918	.249	7.702	1347.18
NS	71	63	41.5	11.3	27.2	1025	3177.5	42537.5	13.387	8.053	.429	18.771	356.08
QB	70	68	60.2	36.5	60.6	2665	13325.0	160432.0	12.040	2.332	.189	12.338	985.82
NB	70	68	51.0	43.3	84.9	2433.	11435.1	124083.0	10.851	2.146	.184	11.663	866.86
NS	70	66	276.8	81.7	29.5	3189	50705.1	882715.2	17.408	2.145	.147	14.591	2014.55
NS	70	65	35.1	8.4	23.9	1114	3564.8	39101.4	10.968	5.979	.456	13.111	322.75
NB	70	65	59.1	41.5	70.2	1652	8260.0	97633.2	11.820	2.727	.303	9.000	789.26
NS	70	64	98.6	58.9	59.1	2610	23751.0	259956.0	10.945	2.728	.225	12.124	1334.50
NS	70	64	121.8	49.7	40.8	2900	42340.0	353220.0	8.342	1.794	.245	7.322	1241.37
NS	70	64	100.0	72.8	72.8	2591	34978.5	259100.0	7.407	2.593	.324	8.003	1619.46
QB	70	63	43.1	22.2	51.5	1839	7539.9	79620.9	10.559	2.774	.219	12.666	510.07
QB	70	62	62.0	41.0	66.1	1918	10165.4	118916.0	11.698	2.325	.240	9.687	698.42
QB	69	67	60.2	44.0	73.1	2030	10556.0	122206.0	11.576	2.338	.188	12.436	923.18
NB	69	67	51.0	46.9	92.0	2378	11890.0	121278.0	10.200	1.895	.176	10.767	938.01
NB	69	65	59.1	51.8	87.6	1981	10301.2	117077.1	11.365	2.215	.245	9.040	1010.74

APPENDIX III
(continued)

NS	69	65	282.0	84.5	30.0	3039	49535.7	856998.0	17.300	2.353	.162	14.524	2302.35
NS	69	64	121.8	58.7	48.2	3081	48987.1	375265.8	7.660	1.938	.259	7.482	1662.07
NS	69	64	99.6	57.8	58.0	2578	24491.0	256768.8	10.484	2.706	.229	11.816	1560.95
QB	69	63	43.1	24.1	55.9	1794	7355.4	77321.4	10.512	2.444	.216	11.314	594.63
NS	69	63	100.0	74.4	74.4	2617	35067.8	261700.0	7.462	2.569	.321	8.003	1990.17
QB	69	62	62.0	45.7	73.7	1804	9741.6	111848.0	11.481	2.185	.239	9.142	791.50
PE	69	60	50.7	19.1	37.7	888	3729.6	45201.6	12.071	2.954	.310	9.530	1376.31
NF	68	67	279.2	103.0	37.8	3148	46590.4	878921.6	18.864	2.448	.155	15.793	2884.59
NB	68	66	51.0	48.0	94.1	1627	7809.6	82977.0	10.625	2.614	.199	13.135	960.31
QB	68	66	60.7	43.1	71.0	2096	10689.6	127227.2	11.901	3.084	.213	14.478	962.49
PE	68	66	54.8	5[illegible]	95.5	1942	17866.4	106421.6	5.956	3.183	.500	6.366	1788.91
NS	68	65	282.0	89.1	31.5	3224	53840.8	909168.0	16.886	2.316	.145	15.972	2361.33
NS	68	64	99.6	48.5	48.6	2786	28695.8	277485.6	9.669	2.127	.222	9.581	1211.31
NB	68	64	63.6	52.8	83.0	1686	9441.6	107229.6	11.357	2.446	.265	9.230	1073.84
NS	68	64	121.8	54.8	44.9	3112	50725.6	378041.6	7.472	1.834	.246	7.455	1570.83
QB	68	63	32.7	15.9	48.6	1697	6448.6	55491.9	8.605	1.986	.180	11.033	396.70
NS	68	63	32.6	10.2	31.2	560	1680.0	18256.0	10.866	8.905	.616	14.456	392.45
QB	68	63	43.0	27.7	64.4	1729	7261.8	74347.0	10.238	2.489	.219	11.365	659.85
NS	68	63	100.0	73.7	73.7	2835	40540.5	283500.0	6.993	2.181	.314	6.945	1970.69
QB	68	62	61.3	44.3	72.2	1801	9005.0	110401.3	12.260	2.521	.225	11.204	1270.49
NF	67	66	284.0	116.3	40.9	2137	32696.1	606908.0	18.600	2.949	.188	15.686	2488.09
PE	67	66	56.1	51.8	92.3	1707	15704.4	95762.7	6.100	2.424	.495	4.596	1105.94
NS	67	65	282.0	92.4	32.7	2891	51170.7	815262.0	15.900	2.530	.163	15.521	2670.58
NB	67	65	63.5	53.8	84.7	1524	8686.8	96774.0	11.100	3.110	.264	11.780	1129.93
PE	67	64	61.3	32.9	53.6	1331	10781.1	81590.3	7.600	2.732	.569	4.801	559.49
NS	67	63	99.6	47.2	47.3	2171	24532.3	216231.6	8.800	2.649	.312	8.490	1257.72
NF	67	63	120.3	104.4	86.7	2348	29819.6	282464.4	9.500	2.439	.255	9.564	2748.80
NS	67	63	121.8	71.7	58.8	3223	54791.0	392561.4	7.200	2.001	.248	8.068	2380.23
NF	67	63	104.6	88.0	84.1	2211	30954.0	231270.6	7.500	2.587	.396	6.532	2200.80
NS	67	63	139.5	69.5	49.8	3033	52774.2	423103.5	8.000	1.671	.182	9.131	2048.20
QB	67	62	43.1	26.5	61.4	1698	6961.8	73183.8	10.500	2.367	.224	10.566	583.57
NS	67	62	33.1	8.9	26.8	516	2064.0	17079.6	8.300	6.459	.817	7.905	268.73
NS	67	62	100.0	71.5	71.5	2543	35602.0	254300.0	7.100	2.333	.335	6.964	255.24
QB	67	61	61.2	43.3	70.7	1463	7607.6	89535.6	11.800	2.905	.272	10.680	779.05
NB	67	60	29.9	8.6	28.7	915	2745.0	27358.5	10.000	2.650	.210	12.619	206.85
PE	67	60	50.7	19.9	39.2	1075	4300.0	54502.5	12.700	3.051	.252	12.107	459.90
NB	67	60	46.6	23.4	50.2	1497	6137.7	69760.2	11.400	2.223	.204	10.897	462.48
QB	67	60	33.0	13.8	41.8	1426	5561.4	47058.0	8.500	1.938	.211	9.134	303.97
NS	66	65	272.0	56.8	21.6	756	13305.6	205632.0	15.500	1.757	.166	10.584	429.94
NS	66	63	121.8	74.2	60.9	3511	61793.6	427639.8	6.900	2.079	.207	10.043	2324.48
NB	66	63	64.4	57.7	89.7	1701	10035.9	109544.4	10.900	3.171	.252	12.593	1270.69
NS	66	63	200.4	82.3	41.5	2911	44829.4	583364.4	13.000	2.343	.197	11.593	2108.50
PE	66	63	61.5	39.0	63.5	2138	20952.4	131487.0	6.300	2.638	.395	6.078	1093.25
NF	66	62	120.3	109.8	91.3	2536	31953.6	305080.2	9.500	2.325	.195	11.923	2927.57
QB	66	62	42.5	25.2	59.8	1612	6770.4	68510.0	10.100	2.476	.224	11.500	528.95

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